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TITLE POST FOAM EXPANSION IN S-IC ELECTRICAL DISTRIBUTORS

MODEL NO. S-IC CONTRACT NO. NAS8-5608

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ABSTRACT

This study was initiated because of several incidences of post expansion of BMS 8-38, Type I, Gr. "FR" foam in S-IC electrical distributors.

Tests on laboratory specimens confirmed that the above-named foam, when processed per 60B32016 and cured at room temperature, does possess post expansion potential when subjected to subsequent elevated temperatures of 150° to 195° F (lower temperatures were not elevated). But, tests also showed that processing the foam at recommended elevated temperatures will produce a foam that is dimensionally stable up to 180°F.

Post foam expansion, forced by heating assembled distributors at 180° F, caused no malfunctions or electrical discontinuities.

With respect to already fabricated distributors, tests showed that: (1) Forcing post foam expansion by heating in an oven under controlled conditions will minimize additional expansion and (2) that proper trimming of the foam surfaces will minimize deflection of the terminal boards and reduce the possibility of foam contact of the p.c. cards and Union Switch Relays.

KEY WORDS

Foam
Cure Cycle
Post Foam Expansion
Distributor
Printed Circuit (p.c.) cards
P.C. Card Cavity
Relay
Relay Cavity

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1.0 OBJECTIVES

Phase Ia:

To determine the effects of the maximum expected environmental temperature. (160 to 190°F), to which a distributor might be subjected, on the dimensional stability of BMS 8-38, Type I, G_R "FR" foam (Stafoam AA1802)① processed per 60B32016. Also, simultaneously, to evaluate various cure cycles as to effectiveness in minimizing post expansion in future distributors.

Phase Ib:

To compare the elevated temperature dimensional stability of similarly processed Stafoam AA1802 and Nopco B 610 foam.②

Phase IIa:

To determine the effects of post foam expansion on electrical continuity and on original dimensions of assembled distributors.

Phase IIb:

To determine the physical and electrical effects of post foam expansion on printed circuit (p.c.) cards, p.c. card components and p.c. card connectors.

Phase IIIa:

To evaluate an "oven fix" procedure as a potential means of preventing excessive post foam expansion in already fabricated distributors.

Phase IIIb:

To evaluate an "autoclave fix" procedure as a potential means of preventing excessive post expansion in already fabricated distributors.

Phase IIIc:

To evaluate the effectiveness of trimmed foam surfaces in preventing damaging post foam expansion.

① Manufactured by Olin Mathieson Chemical Corp.

② Manufactured by Nopco Chemical Company

2.0 BACKGROUND

Reports of "delayed foam expansion" occurring in a limited number of S-IC electrical distributors have been received since July, 1966. But details of this expansion were not clearly defined. Foam expansion was reported to have occurred in three distributors [3] during high temperature qualification testing but this expansion caused no malfunctions.

Due to the lack of reported malfunctions resulting from delayed foam expansion and to the general lack of details about such expansion this situation did not seem to pose any threat to the function of the distributors. But in March of 1967 MSFC's IU distributor, while undergoing test at Douglas' facilities, reportedly expanded an alarming amount. Due to this, tests, which had been initiated in July, 1966, were intensified.

This delayed expansion is theorized to be caused by a number of interrelated conditions:

a. Excessive gas concentration caused by restricted foaming and exothermic heat loss.

b. Incompletely cured foam caused by cooling too rapidly.

c. The cell walls, soften by elevated temperatures, are expanded by excessive internal cell pressure.

3.0 CONCLUSIONS

3.1 GENERAL

All the following conclusions are based on results reported herein:

3.2 PHASE Ia

a. Stafoam AA1802, foamed and cured at room temperature, is dimensionally unstable when exposed to subsequent elevated temperatures in the range of 150° to 195°F. (Lower temperatures were not evaluated).

b. Foaming and curing at the proper elevated temperatures will produce a thermally stable foam that will be satisfactory for foaming S-IC distributors.

[3] Ref. T5-6571, T5-6572, and T5-6373

3.3 PHASE Ib

Nopco B 610 foam (restricted foamed and room temperature cured) is approximately 4 times more thermally stable than similarly processed Stafoam AA1802. But the exothermic temperature generated in metal molds is approximately 90°F greater and the density is 3 to 4 times greater than that of Stafoam.

3.4 PHASE IIa AND PHASE IIb

Post expansion of Stafoam AA1802 will not cause electrical discontinuities by breaking or pulling wires loose when expanded to its maximum limit by heating at 180°F. Nor will expansion, forced at 180°F, cause any malfunctions or relay chatter as a result of the foam pressing against the p.c. card components.

3.5 PHASE IIIa

Oven heating under controlled conditions to force potential post foam expansion is a satisfactory "fix procedure" to minimize additional post expansion.

3.6 PHASE IIIb

The autoclave cycles evaluated in this study did not produce satisfactory results.

3.7 PHASE IIIc

Proper trimming of all foam surfaces will minimize deflection of the terminal boards and will prevent the foam from expanding into the p.c. cards and Union Switch Relays.

4.0 <u>RECOMMENDATIONS</u>

4.1 FOR FUTURE S-IC DISTRIBUTORS

Revise the distributor foaming process to include the following general cure cycle and conduct a development program to improve and make it more adaptable to manufacturing.

Recommended Foaming Procedure to Prevent Post Foam Expansion:

a. Foam in a 195°F preheated mold. Allow to rigidify 0.5 hours @ room temperature.

b. Initial cure: (With restraining cover on) Bake at 150° to 160°F for 1 hour per inch of foam thickness then cure at room temperature for 20 hours, minimum.

c. Post cure: Remove cover and bake 20 to 24 hours @ 195 ± 5°F.

d. Remove excess foam.

4.2 FOR ALREADY FABRICATED DISTRIBUTORS

4.2.1 General

4.2.1.1 Two recommendations to remedy the post foam expansion problem in S-IC electrical distributors are presented in Sections 4.2.2 and 4.2.3. In developing these recommendations, technical considerations were based on over all results obtained from this study. Also, two influencing assumptions were made: (1) For recommendation No. 1 (4.2.2), it is assumed that concerned parties agree to minimize additional post expansion. (2) For No. 2 (4.2.3), it is assumed that additional post expansion does not matter if it does not significantly deflect the terminal boards, contact the relay cards, or Union Switch Relays.

4.2.1.2 A third possible recommendation and, seemingly, the most economic would be to "leave as is" since no malfunctions resulted when expansion was forced to its maximum by heating several distributors to 180°F. However, post foam expansion data in S-IC distributors exposed to temperatures below 180°F over an extended period of time was not determined in this test.

4.2.2 Recommendation No. 1

The detailed procedure is presented in Phase IIa (page 84). The general process is as follows: Force potential post foam expansion out the bottom of the distributor by oven baking at 195 ± 5°F for 24 hours. Remove excess foam. Run functional tests for reliability assurance.

4.2.3 Recommendation No. 2

Completely remove the preformed foam dams, used to restrain the foam during fabrication, from the ends of the relay cavities. In the p.c. card cavity, trim the dam back to drawing dimensions but do not completely remove due to the risk of cutting wires. Remove foam from the horizontal (bottom) surface to the maximum depth possible without contacting wires. This procedure is not recommended for distributors in which the foam cannot be removed without the risk of cutting wires.

5.0 PROCEDURES AND RESULTS

Phase I is broken down into Phase Ia (Section 5.1) and Phase Ib (Section 5.2).

Phase II is broken down into Phase IIa (Section 5.3) and Phase IIb (Section 5.4).

Phase III is broken down into Phase IIIa (Section 5.5), Phase IIIb (Section 5.6), and Phase IIIc (Section 5.7).

Each phase is treated as a complete report (although reference may be made to another phase) consisting, generally, of: Objective, Specimen Identity, Test Procedure, Test Results, and Conclusions and/or Recommendations. Applicable tables and figures are attached at the end of each phase. The numbering system for the tables and figures starts over with (I) and (1), respectively for each phase. The phase number is included for complete identification of tables and figures.

5.1 PHASE Ia

5.1.1 Objective

To determine if the maximum expected environmental temperature (160° to 190°F), to which a distributor might be subjected, would result in post expansion of Stafoam AA1802 when processed per 60B32016 and cured at room temperature. Also, simultaneously, to evaluate various cure cycles as to their effectiveness in minimizing post expansion.

5.1.2 Test Procedure

5.1.2.1 Specimen Molds

Specimen molds (12" x 8" x 3.5") were prepared from nominal 1/10" thick heat treated aluminum alloy. Covers for restricted foamed specimens were made from nominal 1/8" thick aluminum alloy with 1/4" diameter vent holes spaced 1 1/2" apart.

The molds were designed to force post expansion in the foam rise (upward) direction during thermal expsoures.

The 12" x 8" x 3.5" dimensions were chosen to approximate the size of the large foam masses located perpendicular to the ends of the printed circuit card cavity in the distributors.

5.1.2.2 Detailed Procedures

The "Foam Specimen Flow Chart" (Section 5.1.2.4) provides specimen identity, mixing instructions, and details the various cure cycles.

5.1.2.3 General Discussion

a. Free foamed (FF) specimens 1 - 6 were prepared for comparison to similarly processed restricted foamed (RF) specimens 7 - 12, to show the effect of foam rise restriction on post expansion.

b. RF specimens 11 - 13 were foamed and cured at room temperature in accordance with our distributor foaming process, 60B32016. No. 13 was fabricated with a bottom made from fiberglass terminal board material to further simulate an actual distributor.

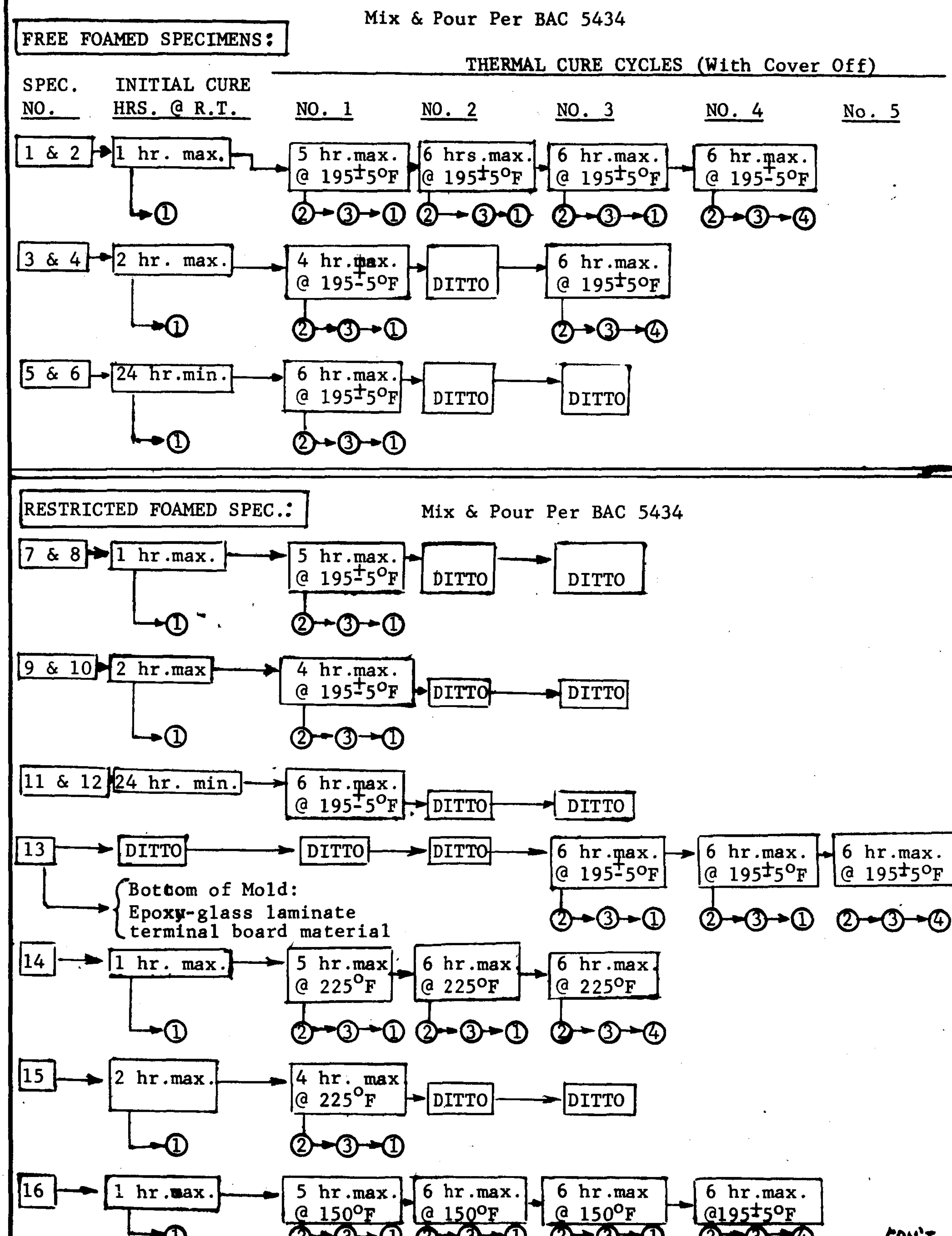
c. RF Specimens 7 - 10 and 14 - 16 were allowed only short room temperature curing times (Rigidifying periods) before subjecting to elevate temperature (with covers off). These cycles were tried in an effort to find a short cure cycle satisfactory to Manufacturing.

d. RF specimens 17 - 24 were prepared to show effects of initial mold temperature on post foam expansion caused from thermal exposure.

5 .1.2.3 General Discussion (Continued)

e. RF specimens 25 - 38 were prepared to show the combined effects of initial mold temperature plus initial cure temperature on post expansion. Until preliminary data became available the mold temperatures were arbitrarily chosen. The reason for the 150°F initial cure temperature was based on the requirements of BAC 5434. The 110°F initial cure temperature, specimens 37 and 38, was chosen because of preliminary results from specimens 20, 23, and 24 which indicated that a satisfactory cure cycle was possible at relatively low temperatures. The initial cure cycle time at temperature was chosen from a scheduling standpoint.

5.1.2.4 FOAM SPECIMEN FLOW CHART



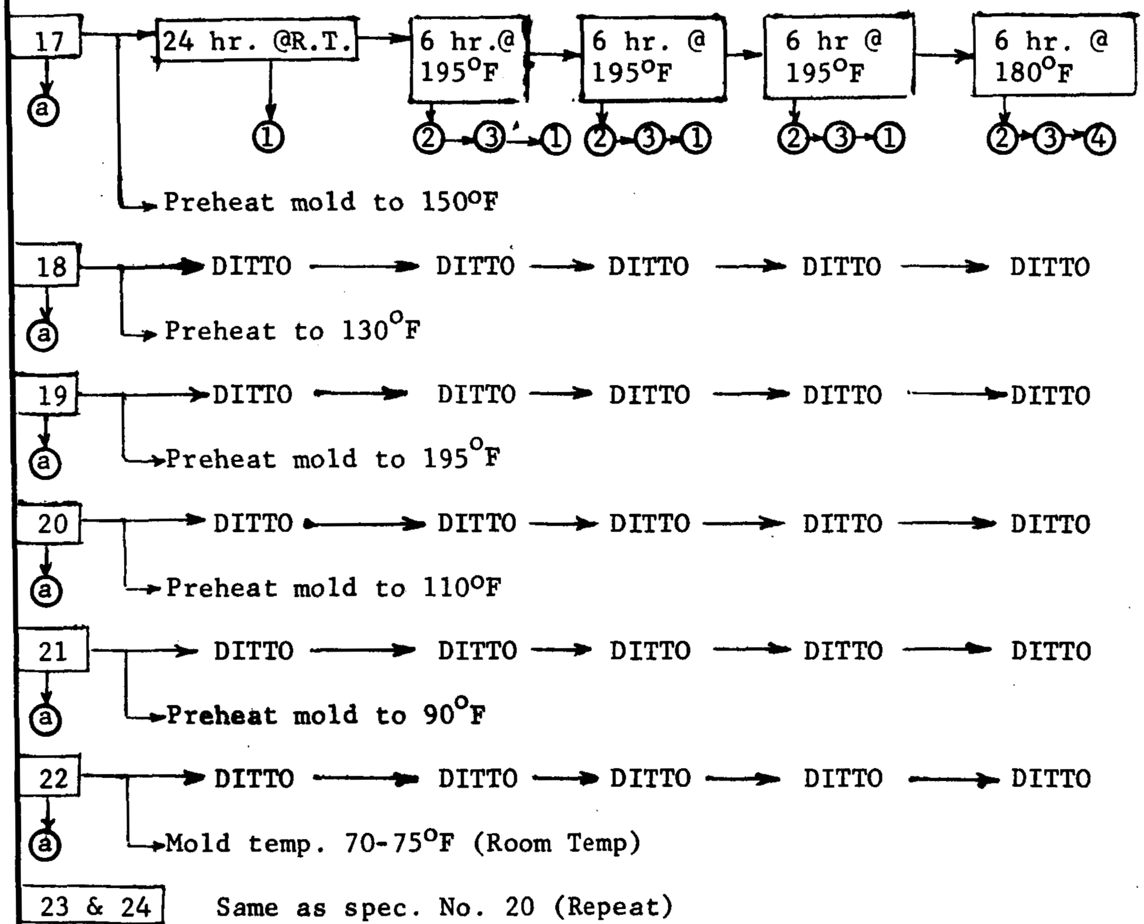
5.1.2.4

FOAM SPECIMEN FLOW CHART CON"T

RESTRICTED FOAMED

THERMAL CURE CYCLES (WITH LID OFF)

SPEC. NO. | INITIAL CURE | No. 1 | No. 2 | No. 3 | No. 4 | No. 5

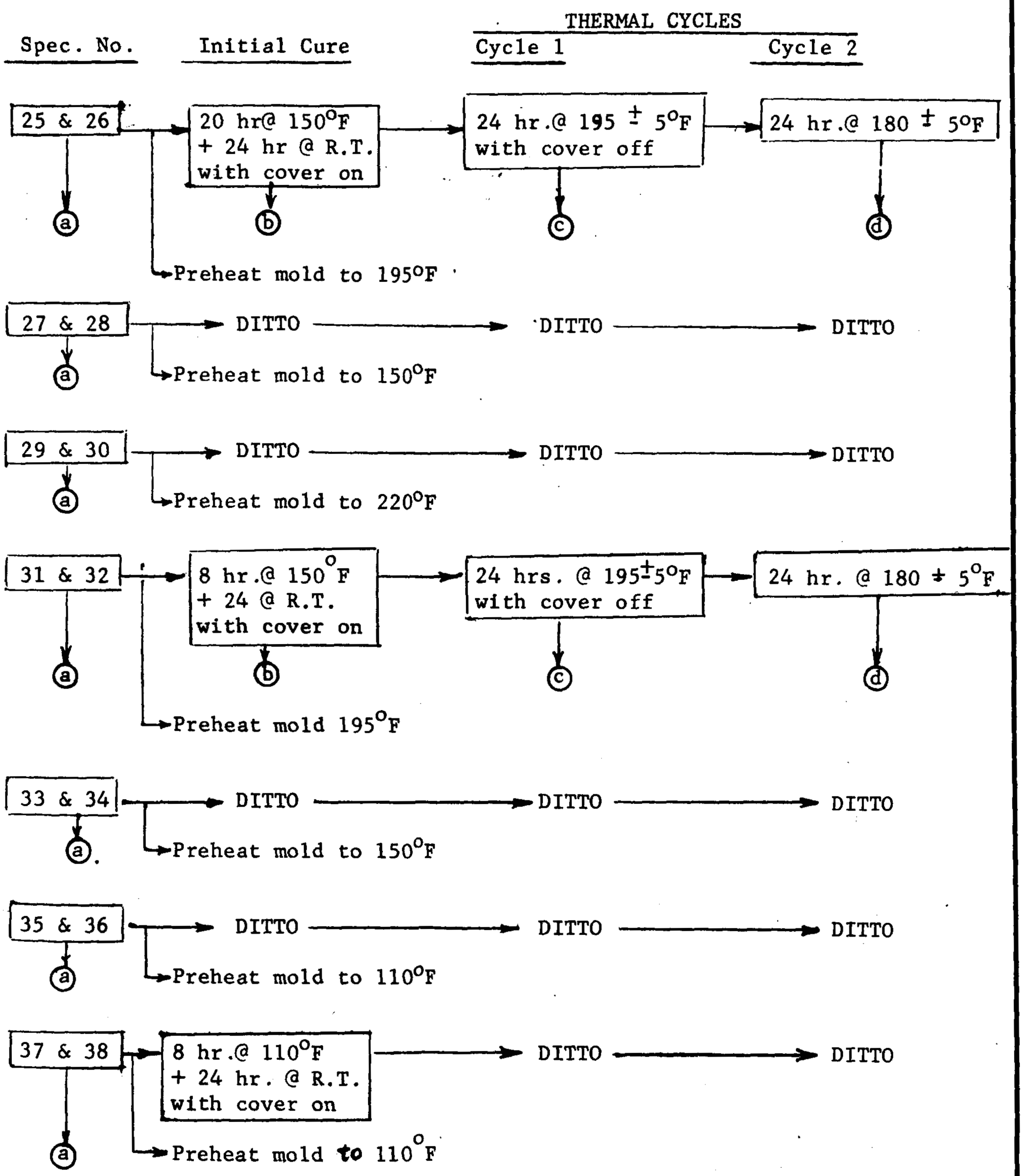


CON'T.

5.1.2.4

FOAM SPECIMEN FLOW CHART (Continued)

RESTRICTED FOAMED:



CON'T.

5.1.2.4 FOAM SPECIMEN FLOW CHART (Continued)

1. Level foam surface to "zero point" prior to thermal cure.
   Zero Point = Top edge of container wall.

2. Measure linear expansion immediately after removing from oven.

3. Measure linear expansion after foam specimen has cooled to room temperature.

4. Remove foam from form and determine density on a 1" x 2" x 2" cube. Examine remainder of foam for anomalies.

a. Insulate mold with prefoamed 1/2" to 1" thick foam blocks leaving only the top open. Preheat to the required temperature for a minimum of 1.0 hours. Pour premixed foam immediately after removing mold from oven.

b. 1/2 Hr. after pouring place specimen into preheated oven.

CAUTION: Handle carefully - DO NOT JAR, BUMP, VIBRATE, DROP, ETC

After removing spec. from oven, allow to cure for a minimum of 24 hours @ R.T.

Remove cover after the 24 hour room cure. DO NOT trim foam surface. Measure the distance of foam above the "zero point". Take measurements across short axis 3" from each end. (Zero point - Top of container wall).

c. Determine ΔL every 6 hours over the 24 hour period, or monitor with Electrical transducer indicators. Measure while hot. DO NOT keep spec. from oven any longer than necessary. Measure while hot at the end of the thermal cycle and remeasure after spec. cools to R.T. (ΔL = Linear expansion (inches) after "X" hours at temperature).

d. Measure before and after heating. Determine ΔL .

5.1.2.5 Measuring Procedures

A dial indicator was used to determine expansion. Measurements were taken across the short axis of the specimen, 3" from each end. High, low and average values were reported.

In addition to determining expansion manually, with a dial indicator, the expansion of specimen 31 - 36 was also monitored, continuously with electrical deflection transducers.

5.1.3 Test Results

5.1.3.1 Presentation of Data

The inches of expansion, determined by manual measurements are tabulated in Table I; this table consists of 12 pages due to the way the data were tabulated. Tables II & III show expansion data determined with electrical deflection transducers (Spec. 31 - 36). Maximum values, extracted from Table I, were plotted in Figures 1 - 11 to show cumulative expansion. Figure 10, 11, 12, and 13 show the combined effects, on post expansion, of initial mold temperature plus initial cure temperature. Figure 13 also shows the worst (where duplicate specimens were run) of the best cure cycles. Figure 14 plots density versus specimen number. This figure together with "Foam Specimen Flow Chart" will show the effects of cure cycle on final foam density.

The following discussion is of a general nature and is limited to details considered pertinent to evaluating the subject foam as to its post expansion potential when processed per the various cycles detailed in Section 5.1.2.4.

5.1.3.2 Post Expansion of 60B32016 Processed BMS 8-38 Type I, G_R "FR" Foam (Stafoam AA 1802)"

Data from specimens 11, 12 and 13 (Figure 6) shows that Stafoam AA1802 is dimensionally unstable at 195°F when "restricted foamed" per our present distributor foaming process, which permits a room temperature cure. The degree of linear expansion ranged from .3 to .5 inches in 8" thick specimens.

Lower temperatures will also cause expansion as evidenced by specimen No. 16, Figure 8. Although this specimen was cured for 17 hours @ 150°F approximately .25 inches linear expansion still occurred (in an 8" thick specimen) upon exposure to 195°F for 6 hours. This statement is further supported by data obtained in a later study (Phase IIIb) which involved exposing a foamed test distributor to 160°F.

Specimen No. 13 which was fabricated with a bottom made from terminal board material showed less post expansion than specimens 11 and 12 which were all metal molds. The probable reason for this

5.1.3.2 (Continued)

is that more of the exothermic heat, required for foaming, was retained in the mold with the non-conductive bottom. This resulted in a more optimum foaming temperature as opposed to foaming in molds that absorb too much of this exothermic heat. The density values support this theory. No. 13 was 2.45 $\#/ft^3$ as compared to 2.53 and 2.71 for specimens 11 and 12.

5.1.3.3 Expansion Rate

In general, most of the expansion that took place over the total thermal exposure time occurred during the first few hours of exposure.

Specimens on which expansion was determined every 6 hours showed that approximately 60 to 80% of the total expansion occurred during the first six hours.

Curves of all specimens show a positive inclination even at the end of their respective thermal cycle periods, indicating a tendency to expand indefinitely if held at a constant temperature. That this is not true, however, in an actual production part, was shown by a later study in which the foam expansion was monitored in several distributors subjected to 180°F for 24 hours - Phase IIa; the results from which showed that the expanding forces were stabilized after approximately 12 hours.

Proof that linear growth of laboratory specimens will not continue at a significant rate if subjected to a temperature slightly lower than the post cure temperature is shown by specimen 25 thru 38 which were heated an additional 24 hours at 180°F following a 24 hour 195°F cycle. Calculations show an increase of only 0% to .2% maximum (in 8" thick specimens) occurring during the 180° cycle.

5.1.3.4 Effects of Restricted Foaming on Post Expansion

Comparison of results from similarly processed "free foamed" and "restricted foamed" specimens (Figures 1 thru 6) indicates that restriction should be limited to the minimum required to effect uniform packing. Expressed as percent of original thickness (8") the free foamed specimens expanded approximately 2 to 4% vs 6 to 8% for the restricted foamed specimens.

5.1.3.5 Effects of Initial Mold Temperature Plus a Room Temperature Initial Cure on Post Expansion (Specimens 17 - 24, Figure 9)

Results show that, in general, the higher the mold temperature at the time of pour the less the degree of initial and total post expansion resulting from subsequent thermal exposure. However, specimens foamed in 110°F molds deviated from the preceeding statement in that they expanded less than specimen foamed at higher initial mold temperatures except for the 195°F specimen.

5.1.3.5 (Continued)

The overall results indicate a definite advantage to foaming in preheated molds or distributors. This is in contrast to the requirements of our present foaming process which calls for a 70 to 90°F mold.

5.1.3.6 Combined Effects of Initial Mold Temperature Plus Initial Cure Temperature on Post Expansion (Specimens 25 - 38; Figures 10 & 11)

In general, these specimens show about the same trend among themselves as did specimens 17 - 24 (Section 5.1.3.5); except that the 195°F mold temperature yielded some what less expansion than the 220° mold, as shown by Figure 10. This indicates that mold temperatures higher than 195°F are of no apparent advantage, with respect to the intended application.

Comparisons, as to the degree of post expansion, of specimens with common initial mold temperatures but with different initial cure temperatures (150°F, 110°F and R.T.) show only a slight advantage of the higher temperatures if compared on the basis of "% expansion as % of original thickness". This is illustrated in Figure 12 which compares data on an equivalent time-temperature basis. But - a significant advantage is shown (45 to 50% at 195° and 150° mold temperature) if compared on the basis of "% difference in degree of expansion". The 110° molds showed only 17% less expansion when compared on this same basis.

The 195° mold/150°F initial cure temperature shows a noticeable advantage over the 110°mold/110°F initial cure. This is shown best by Figure 12.

Varying the time at 150°F during the initial cure (20 hours for specimens 25 - 30 and one hour per inch of thickness (8 hrs) for specimens 31 - 36) made very little difference in the degree of post expansion.

This is shown by comparison of similarily processed specimens in Figures 10, 11, and 12.

5.1.3.7 Comparison of Dimensional Changes Determined With Electrical Deflection Transducers vs. Manually Determined Data:

Data from Table II which shows expansion monitored during the 195°F cycle indicates the same trend as manually determined data. i.e. The average expansion of duplicate specimens 31 and 32 is less than the other specimens. Table III (180° cycle) shows no expansion. This, also, is in line with the manual measurements.

5.1.3.8 Comparison of Best Cure Cycles

Figure 13 compares the worst of the best cure cycles (where specimens were run in duplicate). From this it appears that, from a standpoint

5.1.3.8 (Continued)

of eliminating post expansion, the process to which specimen No. 31 was subjected will yield a satisfactory foam.

5.1.3.9 Foam Quality

The foam quality of all specimens (except for 14 and 15①) appeared to be satisfactory for the intended application. The cell size of the elevated temperature processed foams appeared to be somewhat larger than room temperature processed specimens. However, the cell size was well within the limits called for in BAC 5434.

5.1.3.10 Effects of various Foaming Procedures on Foam Density (Figure 14)

"Free foamed" specimens (1-6) were somewhat less dense than similarly processed "restricted foamed" specimen (7-12). This indicates that' restriction should be held to a minimum, if the density is critical, required to obtain uniform packing.

Density values of "restricted foamed" specimen 17-36, which were foamed in preheated molds were generally lower than "restricted foamed" specimens foamed in room temperature molds. From this it appears that preheating the mold will result in a density closer to the maximum specified by BMS 8-38 (2.3 to 2.5 #/ft^3). Although the density values of some specimens deviate from this statement, the cause is theorized to be from the inherent sensitivity of this particular foam system.i.e. Loss of blowing agent by evaporation during repeated openings of the container; deviating from the specified ratio will also affect the density.

5.1.4 <u>Conclusions and Recommendations</u>

5.1.4.1 The results definitely show that Stafoam AA 1802 (BMS 8-38, Type I, Gr. "FR"), when foamed and cured at room temperature per our 60B32016 foaming process, is dimensionally unstable when exposed to subsequent elevated temperatures in the range of 150 to 195°F. Expansion at lower temperatures was not determined.

5.1.4.2 With consideration as to which foaming procedure and cure cycle resulted in the least initial and least total post expansion, caused by thermal exposure, it appears that the following general process will produce a satisfactory foam:

1. Foam in a 195°F mold.

2. Initial Cure: After 30 minutes rigidifying time cure at 150° to 160°F for one hour per inch of linear foam thickness then cure

① Horizontal stress cracks developed in 14 and 15 due to too high a temperature exposure (with covers off) too soon after foaming. See Foam Flow Chart for exact conditions.

5.1.4.2 (Continued)

20 to 24 hours minimum at room temperature. (Restraining cover shall be in place during the initial cure).

3. Post Cure: Remove cover and cure for 20 to 24 hours at 195 $\pm$ 5^{o}F.

4. Remove excess foam.

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R. T. CURE	HEAT CURE CYCLE: CYC. NO.	HEAT CURE CYCLE: CONDITIONS °F / HRS.	INCHES EXPANSION: HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
1	1 hr.	1	195° / 5	.215	.185	.157	.189	.161	.134
		2	195° / 6	.047	.039	.026	.029	.023	.017
		3	195° / 6	.032	.025	.013	.015	.009	.002
Density :	2.35 #/ft³	4	195° / 6	.029	.019	.011	.027	.012	.003
2	1 hr	1	195° / 5	.226	.206	.190	.196	.176	.159
		2	195° / 6	.040	.036	.028	.021	.017	.012
		3	195° / 6	.041	.031	.021	.019	.010	.003
Density :	2.47 #/ft³	4	195° / 6	.026	.018	.006	.016	.005	0
3	2 hrs	1	195° / 4	.209	.183	.153	.193	.167	.137
		2	195° / 6	.074	.054	.032	.050	.031	.009
Density :	2.41 #/ft³	3	195° / 6	.029	.025	.020	.017	.008	.0
4	2 hrs.	1	195° / 4	.173	.158	.136	.165	.140	.118
		2	195° / 6	.047	.038	.027	.026	.020	.014
Density :	2.46 #/ft³	3	195° / 6	.027	.024	.022	.011	.006	.002

MOLD: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction. Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 1 of 12)

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TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	HEAT CURE CYCLE CONDITIONS °F / HRS	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
5	24 hrs	1	195° / 6	.135	.115	.068	.122	.103	.052
		2	195° / 6	.024	.020	.015	.007	.003	.0
DENSITY:	2.23 #/ft³	3	195° / 6	.020	.011	.0	.004	.002	.0
6	24 hrs	1	195° / 6	.154	.133	.124	.138	.112	.092
		2	195° / 6	.030	.023	.018	.011	.006	.003
DENSITY:	2.22 #/ft³	3	195° / 6	.019	.018	.017	.008	.006	.002
7	1 hr	1	195° / 5	.457	.417	.395	.438	.403	.367
		2	195° / 6	.049	.047	.041	.038	.035	.033
DENSITY:	2.60 #/ft³	3	195° / 6	.035	.030	.027	.017	.016	.014
8	1 hr	1	195° / 5	.572	.395	.357	.427	.382	.346
		2	195° / 6	.057	.044	.038	.047	.032	.025
DENSITY:	2.59 #/ft³	3	195° / 6	.026	.022	.017	.015	.011	.002

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction. Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 2 of 12)

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	HEAT CURE CYCLE CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
9	2 hr.	1	195° / 4	.454	.432	.419	.449	.422	.405
		2	195° / 6	.049	.033	.017	.033	.020	.0
DENSITY:	2.60 #/FT.³	3	195° / 6	.024	.021	.018	.015	.012	.006
10	2 hr.	1	195° / 4	.427	.406	.368	.413	.396	.359
		2	195° / 6	.072	.068	.064	.062	.052	.046
DENSITY:	2.59 #/FT.³	3	195° / 6	.024	.022	.020	.015	.011	.006
11	24 hr.	1	195° / 6	.385	.380	.375	.375	.370	.365
		2	195° / 6	.059	.049	.039	.046	.041	.030
DENSITY:	2.53 #/FT.³	3	195° / 6	.037	.032	.025	.017	.014	.011
12	24 hr.	1	195° / 6	.395	.378	.340	.406	.371	.330
		2	195° / 6	.060	.055	.045	.046	.039	.033
Density:	2.71 #/FT.³	3	195° / 6	.019	.014	.009	.011	.008	.004

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction.
Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 3 of 12)

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TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
13	24 hr.	1	195° / 6	.287	.260	.217	.247	.212	.157
		2	195° / 6	.057	.043	.032	.017	.014	.007
		3	195° / 6	.047	.040	.035	.007	.004	.002
		4	195° / 6	.022	.018	.017	.017	.008	.003
Density:	2.45 #/ft.³	5	195° / 6	.037	.027	.012	.009	.005	.0
14	1 hr.	1	225° / 5	.840	.825	.808	.830	.788	.727
		2	225° / 6	.207	.194	.175	.193	.178	.116
Density:	2.59 #/ft.³	3	225° / 6	.074	.069	.065	.060	.055	.052
15	2 hr.	1	225° / 4	.765	.724	.700	.732	.681	.650
		2	225° / 6	.184	.172	.154	.161	.157	.137
Density:	2.59 #/ft.³	3	225° / 6	.054	.041	.029	.025	.019	.012

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction. Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 4 of 12)

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TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	HEAT CURE CYCLE CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
16	1 hr	1	150° / 5	.137	.124	.102	.127	.115	.091
		2	150° / 6	.025	.017	.007	.012	.005	.0
		3	150° / 6	.020	.013	.006	.009	.004	.0
Density:	2.62 #/FT³	4	195° / 6	.244	.225	.197	.224	.210	.187
17	24 hr.	1	195° / 6	.191	.151	.122	.161	.132	.102
		2	195° / 6	.033	.023	0	.017	.009	0
		3	195° / 6	.020	.010	0	.007	.002	0
Density:	2.37 #/FT³	4	180° / 6	.017	.011	.002	.010	.005	0
18	24 hr.	1	195° / 6	.260	.221	.185	.248	.210	.173
		2	195° / 6	.046	.024	.009	.037	.020	.007
		3	195° / 6	.024	.018	.012	.010	.005	.002
Density:	2.63 #/FT³	4	180° / 6	.020	.013	.002	.010	.005	0

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction.
Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 5 of 12)

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REV. SYM.

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	HEAT CURE CYCLE CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
19	24 hr.	1	195° / 6	.050	.026	.015	.046	.024	.014
		2	195° / 6	.036	.017	0	.026	.007	0
		3	195° / 6	.042	.018	0	.030	.008	0
Density:	2.19 #/FT³	4	180° / 6	.020	.009	.004	.005	.004	0
20	24 hr.	1	195° / 6	.152	.150	.147	.146	.143	.140
		2	195° / 6	.010	.005	0	.007	.003	0
		3	195° / 6	.026	.013	0	.018	.007	0
Density:	2.[illegible] #/FT³	4	180° / 6	.010	.006	.002	.009	.007	.001
21	24 hr.	1	195° / 6	.350	.293	.260	.277	.244	.230
		2	195° / 6	.036	.024	.013	.012	.005	0
		3	195° / 6	.072	.051	.030	.051	.035	.018
Density:	2.49 #/FT³	4	180° / 6	.020	.012	.004	.004	.003	.001

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction. Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 6 of 12)

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	HEAT CURE CYCLE CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
22	24 hr.	1	195° / 6	.530	.510	.505	.490	.468	.450
		2	195° / 6	.080	.069	.060	.041	.036	.032
		3	195° / 6	.120	.115	.110	.075	.070	.065
Density:	2.19 #/ft³	4	180° / 6	.032	.027	.015	.003	.001	0

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction. Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (page 7 of 12)

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
#23	24 hrs	1	195° / 6	.134	.117	.096	.120	.097	.075
		2	195° / 6	.029	.021	.014	.009	.002	0
		3	195° / 6	.040	.026	.019	.011	.006	.002
Density:	2.19 #/FT.³	4	180° / 24	.025	.015	.008	.005	.002	0
#24	24 hrs	1	195° / 6	.130	.117	.103	.107	.100	.093
		2	195° / 6	.035	.024	.015	.013	.008	.004
		3	195° / 6	.045	.028	.014	.039	.020	.012
Density:	2.23 #/FT.³	4	180° / 24	.024	.014	.001	.003	.001	0
#25	30 MIN	1	195° / 6	.062	.045	.028			
		2	195° / 6	.012	.010	.008			
							TOTAL COLD @ 24 hrs		
		3	185° / 12	.013	.009	.004	.064	.053	.033
Density:	2.31 #/FT.³	4	180° / 24	.010	.009	.006	.006	-.001	-.004

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction.
Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 8 of 12)

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	HEAT CURE CYCLE CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
#26	30 MIN	1	195° / 6	.038	.034	.025			
		2	195° / 6	.007	.004	.001			
							TOTAL	COLD @	24 hrs.
		3	195° / 12	.005	.003	.001	.035	.028	.022
Density:	2.10 #/FT.³	4	180° / 24	.015	.010	.005	-.009	-.005	-.001
#27	30 MIN	1	195° / 6	.096	.084	.070			
		2	195° / 6	.016	.014	.010			
							TOTAL	COLD @	24 hrs.
		3	195° / 12	.023	.018	.010	.117	.099	.084
Density:	2.30 #/FT.³	4	180° / 24	.019	.011	0	+.006	0	-.005
#28	30 MIN	1	195° / 6	.094	.093	.092			
		2	195° / 6	.013	.008	.004			
							TOTAL	COLD @	24 hrs.
		3	195° / 12	.022	.013	.002	.112	.104	.092
Density:	2.32 #/FT.³	4	180° / 24	.017	.014	.011	.007	.005	.002

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction. Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 9 of 12)

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE: CYC. NO.	HEAT CURE CYCLE: CONDITIONS °F / HRS.	INCHES EXPANSION: HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
#29	30 MIN	1	195° / 6	.059	.030	.004			
		2	195° / 6	.023	.011	.001			
							TOTAL	COLD @	24 hrs.
		3	195° / 12	.019	.011	-.008	.061	.038	.008
Density:	2.31 #/FT.³	4	180° / 24	.018	.011	0	.009	.005	-.004
#30	30 MIN	1	195° / 6	.049	.041	.028			
		2	195° / 6	.010	.009	.007			
							TOTAL	COLD @	24 hrs
		3	195° / 12	.016	.012	.008	.059	.047	.036
Density:	2.29 #/FT.³	4	180° / 24	.023	.012	.005	.016	.005	0
#31	30 MIN	1	195° / 24	.074	.065	.055	.073	.060	.052
Density:	2.37 #/FT.³	2	180° / 24	.007	.004	.001	.003	+.002	-.002
#32	30 MIN	1	1[illegible]° / 24	.068	.056	.041	.058	.046	.035
Density:	2.40 #/FT.³	2	180° / 24	.003	.002	.001	.002	-.001	-.002

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction.
Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 10 of 12)

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	HEAT CURE CYCLE CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
#33	30 MIN	1	195°/24	.146	.112	.087	.131	.099	.067
Density:	2.45 #/FT.³	2	180°/24	.012	.004	0	.010	.003	0
#34	30 MIN	1	195°/24	.136	.109	.083	.138	.105	.076
Density:	2.52 #/FT.³	2	180°/24	.005	.003	0	.002	.001	0
#35	30 MIN.	1	195°/24	.190	.151	.121	.181	.145	.120
Density:	2.37 #/FT.³	2	180°/24	.002	.001	0	.002	.001	0
#36	30 MIN.	1	195°/24	.175	.149	.125	.171	.145	.122
Density:	2.42 #/FT.³	2	180°/24	.002	.0005	0	0	0	0

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction.
Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 11 of 12)

TABLE

LINEAR EXPANSION OF BMS 8-38 TYPE I, GR FR FOAM AFTER VARIOUS INITIAL CURES FOLLOWED BY REPEATED HEAT CURE CYCLES.

SPECIMEN NO.	INITIAL R.T. CURE	HEAT CURE CYCLE CYC. NO.	CONDITIONS °F / HRS.	INCHES EXPANSION HOT MAX.	HOT AVG.	HOT MIN.	COLD MAX.	COLD AVG.	COLD MIN.
#37	30 MIN	1	195° / 6	.134	.113	.105			
							TOTAL	COLD @	24 hrs.
		2	195° / 16	.036	.021	.011	.141	.129	.116
Density:	2.18 #/FT³	3	180° / 24	.014	.010	.006	.011	.004	-.003
#38	30 MIN	1	195 / 6	.138	.131	.124			
							TOTAL	COLD @	24 hrs
		2	195 / 18	.027	.020	.014	.149	.141	.135
Density:	2.72 #/FT³	3	180 / 24	.016	.009	.004	.008	.003	-.002

Mold: 12" x 8" x 3.5"; Expansion in 8" (foam rise) direction.
Measurements taken across 3.5" direction 3" from each end.

DETERMINATION OF DIMENSIONAL STABILITY OF CURED BMS 8-38 TYPE I, GR.FR FOAM TABLE I, PHASE Ia (Page 12 + 12)

FOAM BOX NOMENCLATURE Test Condition: 195°F

FOAM BOX DEFLECTION AND TEMPERATURE DATA
FOAM BOX SERIAL NUMBER 31, 32, 33, 34, 35, 36

DATE 3-20-67

TIME	DEFLECTION IN INCHES						TEMPERATURE °F			REMARKS
MIN/HRS	D31	D32	D33	D34	D35	D36	TC (031)	TC (033)	TC (036)	
0	+.04	-.01	-.03	-.01	0	-.01	75	75	75	thermocouples (TC) were
15	+.04	0	-.03	-.01	0	-.01	83	87	83	embedded 4" in foam.
30	+.02	-.01	-.03	-.02	0	-.01	97	103	97	
45	+.04	-.01	-.03	-.01	0	-.01	111	118	112	
60	+.04	0	-.03	0	0	-.01	125	134	126	
75	+.03	-.01	-.03	0	0	-.01	139	147	139	
90	+.05	+.01	-.05	0	+.01	0	153	160	153	
105	0	-.01	0	+.01	+.03	-.01	163	171	163	
120	+.04	+.01	0	+.01	+.04	+.03	172	177	172	
135	+.05	+.01	+.01	+.02	+.03	+.01	175	177	175	
150	+.05	0	+.03	+.02	+.06	+.05	178	182	177	
165	+.05	+.01	+.03	+.02	+.06	+.05	182	183	182	
180	+.04	+.01	+.03	+.04	+.06	+.05	183	184	183	
195	+.05	+.01	+.03	+.04	+.06	+.05	183	184	183	
210	+.04	+.01	+.04	+.04	+.06	+.05	183	184	183	
225	+.05	+.01	+.03	+.04	+.06	+.06	184	185	184	
240	+.05	+.02	+.03	+.05	+.06	+.06	187	193	187	
8 HRS	+.08	+.05	+.06	+.07	+.11	+.11	197	198	197	
12 HRS							198	198	198	NO DEFLECTION DATA - CHART PAPER DEPLETED
16 HRS							198	199	198	NO DEFLECTION DATA - CHART PAPER DEPLETED
21 HRS	+.10	+.06	+.10	+.10	+.14	+.14	197	198	198	
Full Scale Deflection	2.0	2.0	2.0	2.0	2.0	2.0				Accuracy: ±5% of full scale
	TIME OF FIRST DEFLECTION									

Determination of Dimensional Stability of Cured BMS 8-38, Type I, Gr. "FR" Foam, Phase Ia, Table II

REV. SYM.

FOAM BOX NOMENCLATURE Test Conditions: 180°F

FOAM BOX DEFLECTION AND TEMPERATURE DATA
FOAM BOX SERIAL NUMBER 31, 32, 33, 34, 35, 36

DATE 3-20-67

TIME	DEFLECTION IN INCHES								TEMPERATURE °F						REMARKS
MIN/HRS	D 31	D 32	D 33	D 34	D 35	D 36			TC (031)		TC (033)	TC (036)			
0	-.01	0	-.01	0	0	0			75		75	75			Thermocouples (TC) were
15	0	+.01	0	0	0	0			85		87	86			embedded 4" in foam.
30	-.01	+.01	0	0	0	0			102		100	97			
45	0	+.01	0	0	0	0			115		114	107			
60	-.01	0	-.02	0	0	0			127		127	120			
75	-.01	0	-.02	-.01	-.01	0			141		140	133			
90	-.01	0	0	0	0	0			153		152	144			
105	-.01	0	0	0	-.01	0			163		162	155			
120	-.01	-.01	0	-.01	-.01	0			167		166	163			
135	-.01	0	-.02	-.01	0	-.01			171		170	166			
150	-.01	0	0	-.01	-.01	0			173		173	170			
165	-.01	0	-.02	-.01	-.01	-.01			174		174	172			
180	-.01	0	0	-.01	-.01	-.01			174		174	173			
195	-.02	0	0	0	-.01	-.01			174		174	173			
210	-.01	0	0	0	-.01	-.01			175		175	174			
225	-.01	0	0	0	-.01	-.01			175		175	174			
240	-.01	0	0	-.01	-.01	-.01			175		175	174			
8 HRS	-.01	-.0	-.02	-.01	-.01	-.01			176		176	176			
12 HRS	-.01	-.01	0	-.02	-.01	0			176		176	176			
16 HRS	-.02	-.01	0	-.02	0	-.01			176		176	176			
20 HRS	-.01	-.01	0	0	-.01	-.01			176		177	176			
24 HRS	-.01	-.01	0	-.02	-.01	-.02			173		173	173			
Full Scale Deflection	.50	.50	.50	.50	.50	.50									Accuracy: ±5% of full scale
			TIME OF FIRST DEFLECTION												

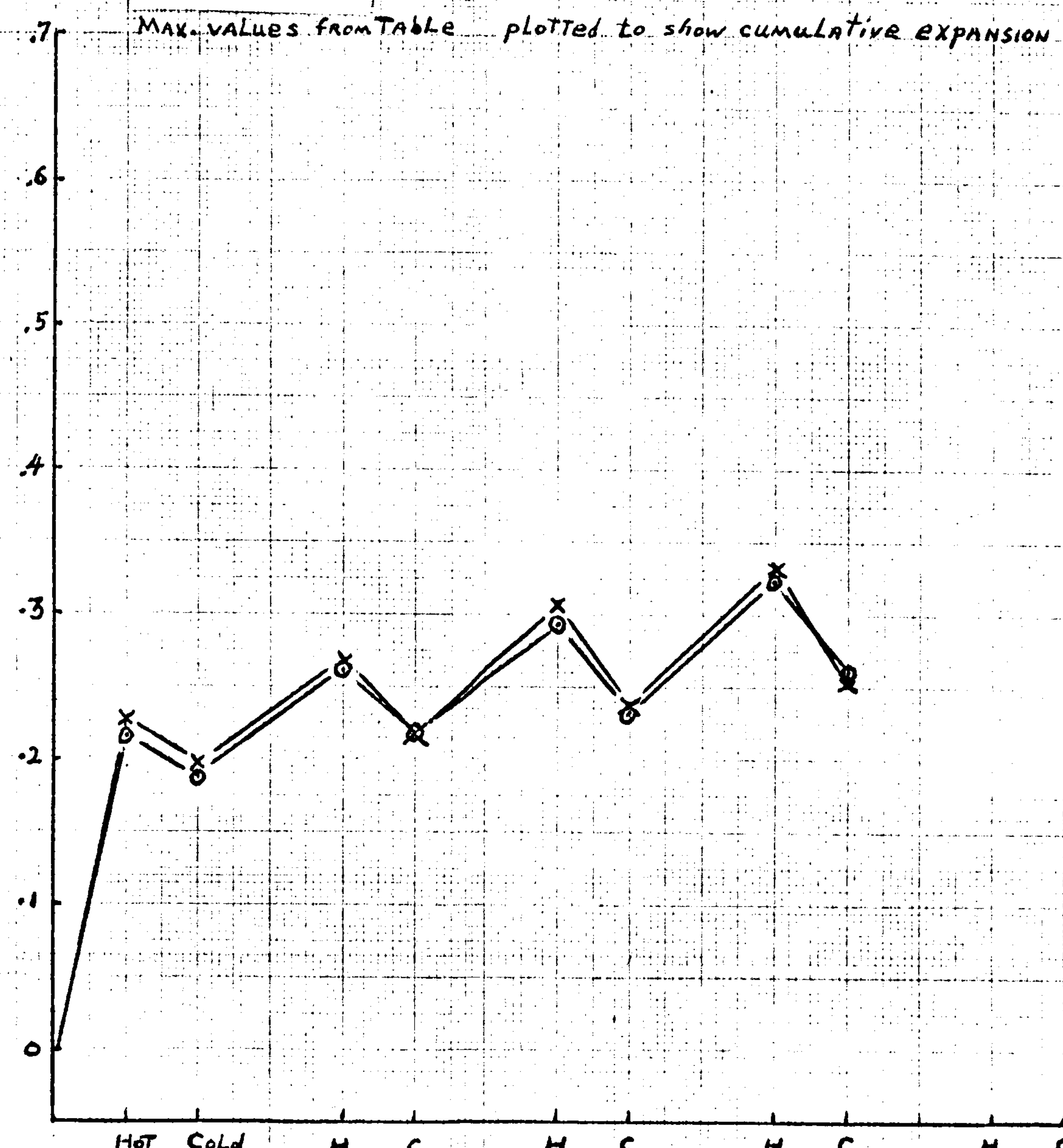
Determination of Dimensional Stability of Cured BMS 8-38, Type I, Gr. "FR" Foam, Phase Ia, Table III

REV. SYM. ______

Specimen Data:

No.		Initial Cure	Density	SYMBOL
1	Free Foamed	1 Hr @ R.T.	2.35 #/ft.^{3}	⊙
2	Free Foamed	1 Hr @ R.T.	2.47 #/ft^3	X

Spec. size: 12"x8"x3.5"; EXPANSION IN 8" direction



CYCLE No. →	1	2	3	4	5
Temp. °F →	195	195	195	195	195
Hrs. @ Temp. →	5	6	6	6	

CALC		REVISED	DATE	BMS 8-38 Type I, Gr. "FR" Rigid Foam Linear Expansion of 8" THK. Spec. Vs. Elevated Temp. Cycling. PHASE IA, Figure 1
CHECK				
APR				T5-6556-13
APR				THE BOEING COMPANY

US 4013 8000

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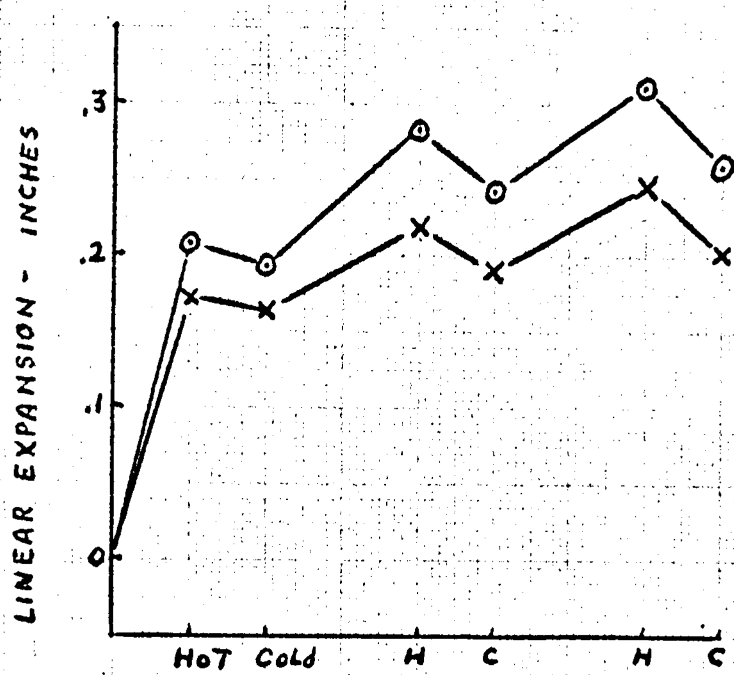
Specimen Data

No.		Initial Cure	Density	Symbol
3	Free Foam	2 Hr @ R.T.	2.41 #/ft.^{3}	⊙
4	Free Foam	2 Hr @ R.T.	2.46 #/ft.^{3}	X

Spec. size: 12" x 8" x 3.5"; Expansion in 8" direction.
Max. values from Table plotted to show cumulative expansion.



CYCLE NO.	1	2	3
Temp. °F	195	195	195
Hrs. @ Temp.	4	6	6

	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					BMS 8-38 Type I, Gr. "FR" Rigid Foam. Linear Expansion of 8" THK. Spec. Vs Elevated Temp. Cycling. Phase Ia, Figure 2	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV. 12-64

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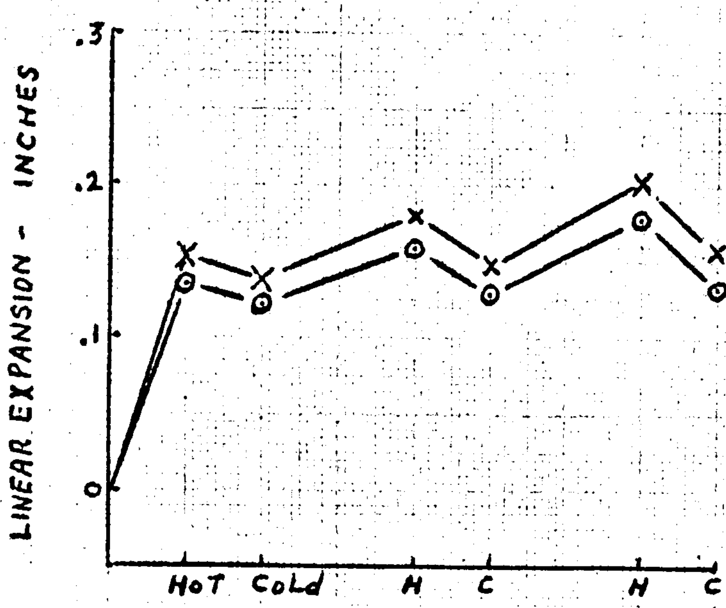
REV LTR

BOEING NO. T5-6556-13

Specimen Data:

No.		Initial Cure	Density	Symbol
5	Free Foamed	24 Hr @ R.T.	2.23 #/FT³	⊙
6	Free Foamed	24 Hr @ R.T.	2.22 #/FT³	X

Spec. size: 12" x 8" x 3.5"; Expansion in 8" direction.
Max. values from Table plotted to show cumulative expansion.



CYCLE NO.	1	2	3
Temp. · °F	195	195	195
Hrs. @ Temp.	6	6	6

	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					BMS 8-38 Type I, Gr. "FR" Rigid Foam. Linear Expansion of 8" THK. Spec. Vs Elecated Temp. Cycling PHase Ia, Figure 3	
CHECK						
APPD.						
APPD.						

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REV LTR

BOEING NO. T5-6556-13

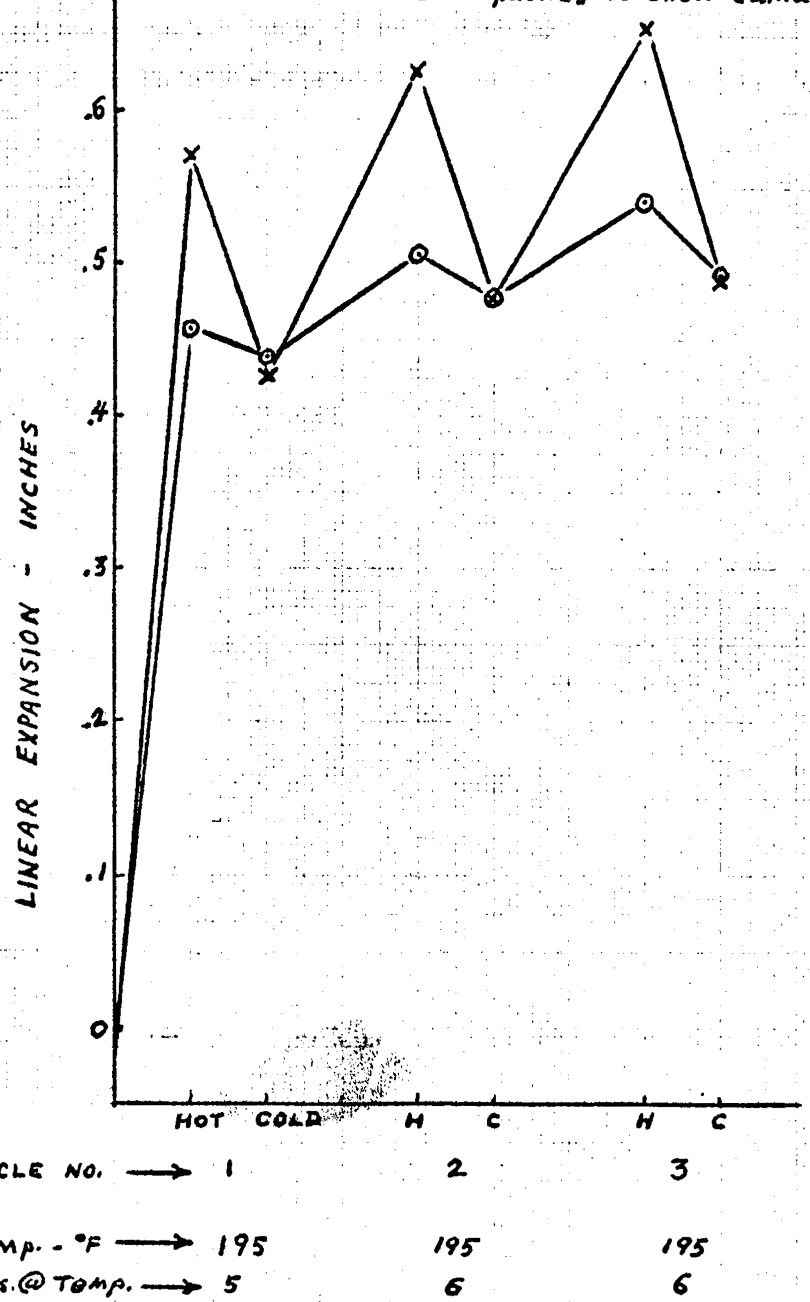
SH. 33

Specimen Data:

No.		Initial Cure	Density	Symbol
7	Restricted Foamed	1 Hr @ R.T.	2.22 #/ft.³	⊙
8	Restricted Foamed	1 Hr @ R.T.	2.59 #/ft.³	X

Spec. Size: 12" x 8" x 3.5"; Expansion in 8" direction.

MAX. values from Table plotted to show cumulative expansion.



	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					BMS 8-38 Type I, Gr. "FR" Rigid Foam. Linear Expansion of 8" THK. Spec. vs Elevated Temp. Cycling. Figure 4, PHase I2	
CHECK						
APPD.						
APPD						

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REV LTR

BOEING NO. T5-6556-13

SH. 34

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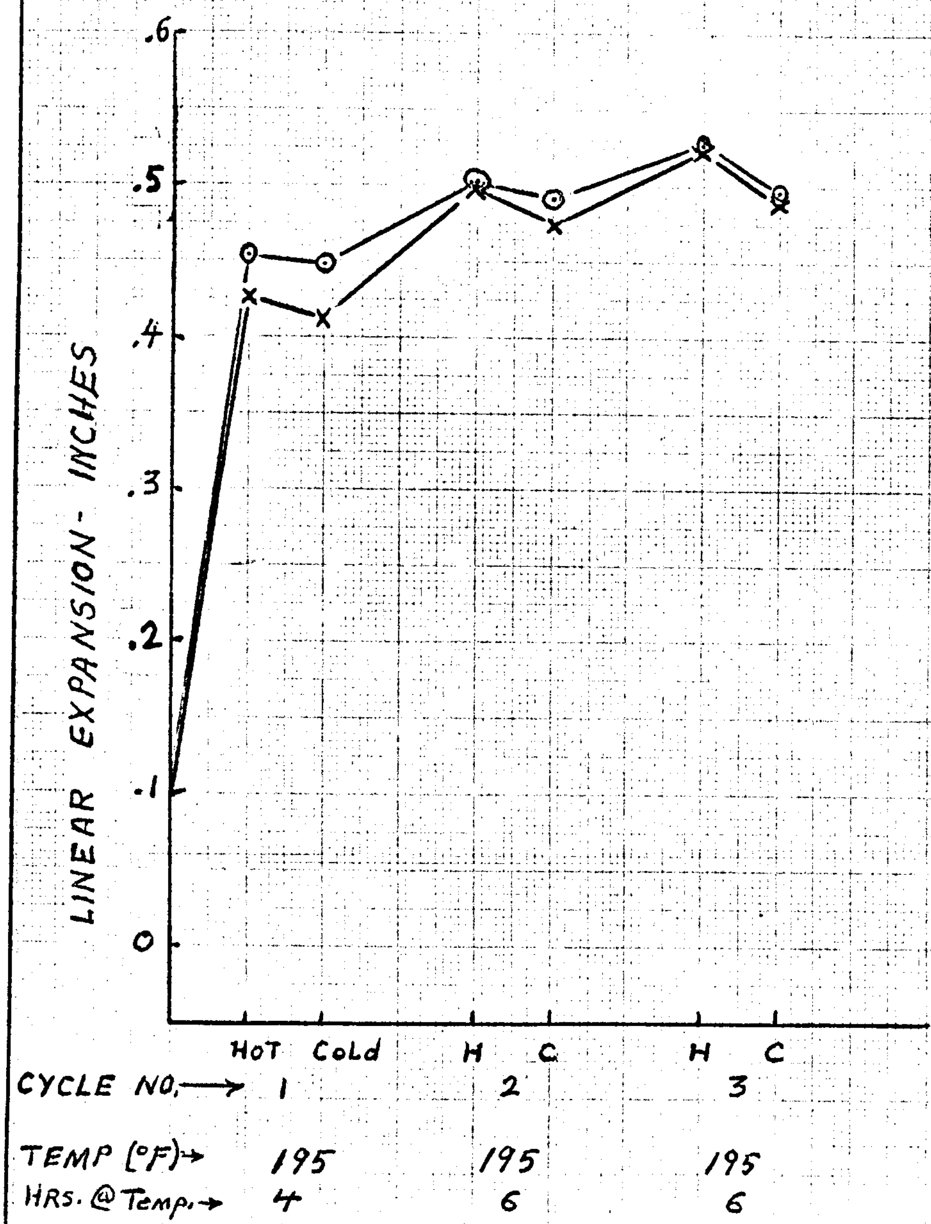
Specimen Data:

No.		Initial Cure	Density	Symbol
9	Restricted Foamed	2HR @ R.T.	2.60 #/ft³	⊙
10	Restricted Foamed	2HR @ R.T.	2.59 #/ft³	X

Spec. size: 12"x8"x3.5"; Expansion in 8" direction.

Max. values from table plotted to show cumulative expansion.



CALC			REVISED	DATE	BMS 8-38, Type I, Gr. "FR" Rigid Foam. Linear Expansion of 8" THK. Spec. Vs. Elevated Temp. Cycling. Phase Ia, Figure 5	T5-6556-1B
CHECK						
APR						
APR					THE BOEING COMPANY	PAGE 35

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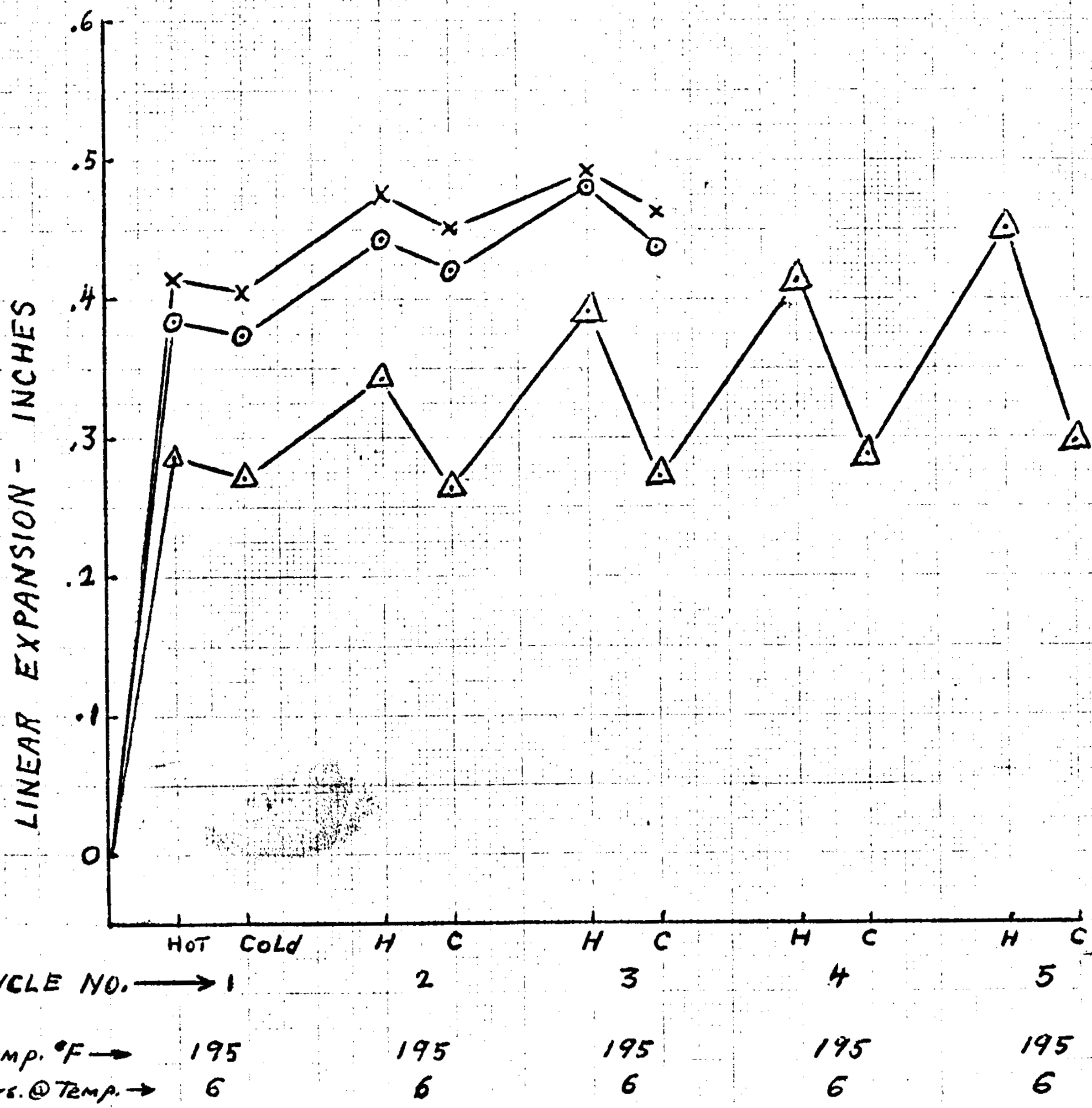
Specimen Data:

No.		Initial Cure	Density	Symbol
11	Restricted Foamed	24 Hr. @ R.T.	2.53 #/ft³	⊙
12	Restricted Foamed	24 Hr. @ R.T.	2.71 #/ft³	×
13	Restricted Foamed	24 Hr. @ R.T.	2.45 #/ft³	△

Spec. size: 12"×8"×3.5"; Expansion in 8" direction
MAX. values from Table plotted to show cumulative expansion.



CALC			REVISED	DATE	BMS 8-38 Type I, Gr. "FR" Rigid Foam. Linear Expansion of 8" THK. Spec. Vs. Elevated Temp. Cycling. PHase Ia, Figure 6	T5-6556-13
CHECK						
APR						
APR					THE BOEING COMPANY	PAGE 36

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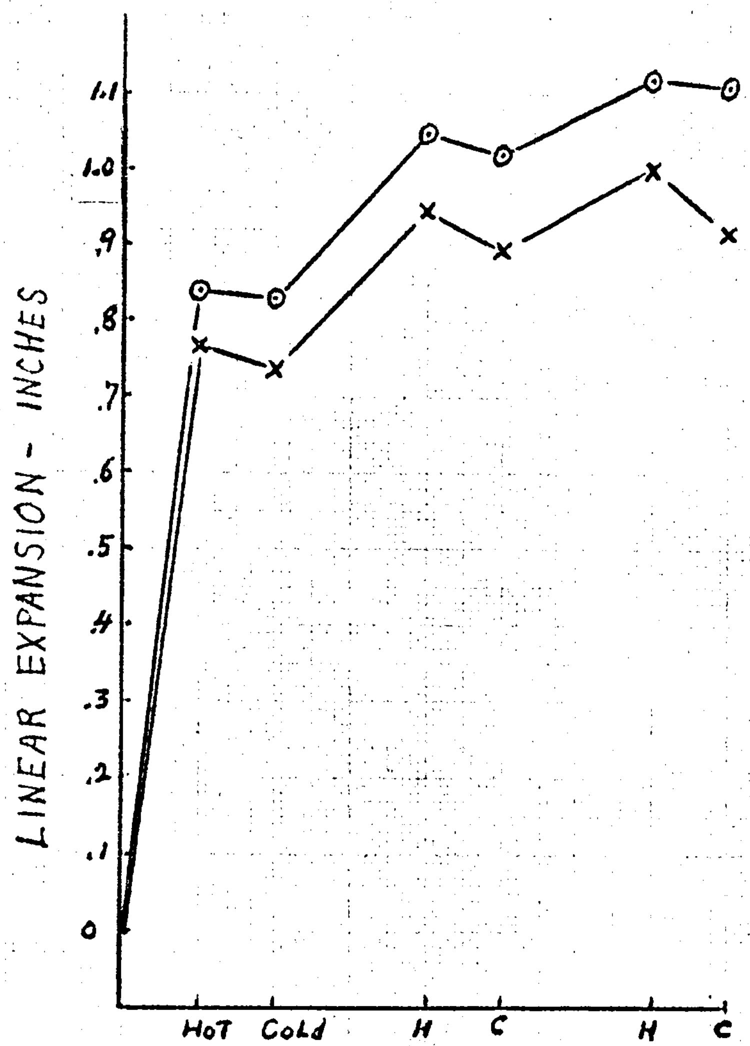
Specimen Data:

No.		Initial Cure	Density	Symbol
14	Restricted Foamed	1 Hr @ R.T.	2.59 #/ft.^{3}	⊙
15	Restricted Foamed	2 Hr @ R.T.	2.59 #/ft.^{3}	X

Spec. size: 12"x8"x3.5"; Expansion in 8" direction.
Max. values from Table plotted to show cumulative expansion.



CYCLE NO. 1 2 3

Temp. - °F: 225 225 225

Hrs. @ Temp: ⊙ = 5 Hrs. X = 4 Hrs. ⊙ = 6 X = 6 ⊙ = 6 X = 6

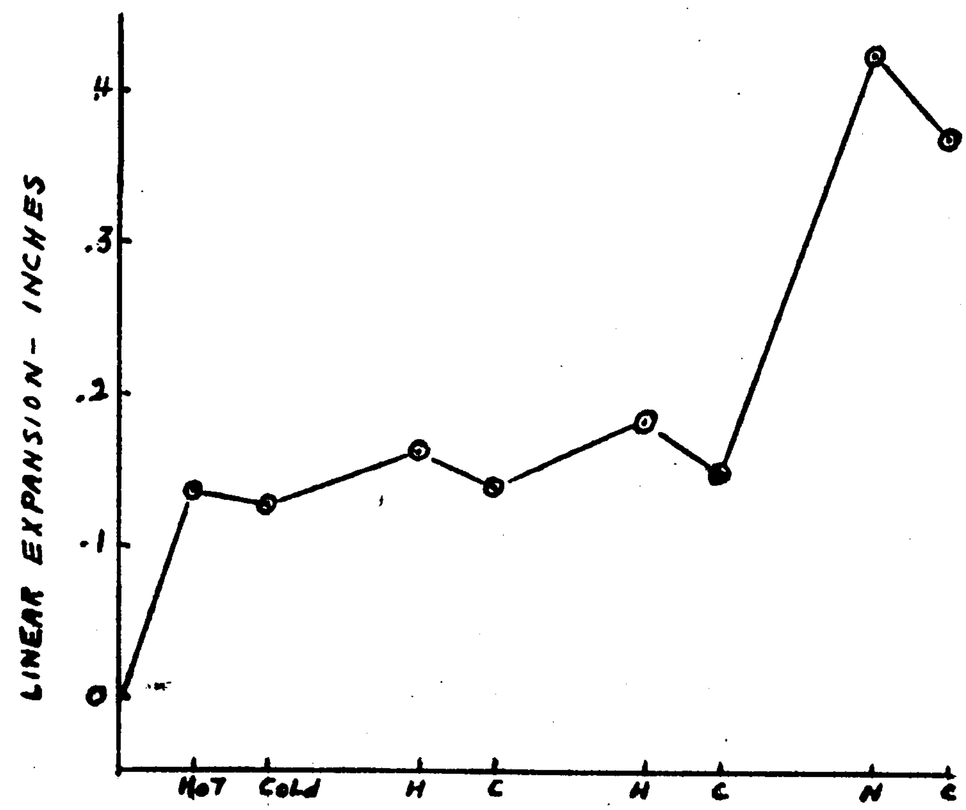
	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					BMS 8-38 Type I, Gr. "FR" Rigid Foam Linear Expansion of 8" THK. Spec. Vs Elevated Temp. Cycling. Phase Ia, Figure 7	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV. 12-64

Specimen Data:

No.		Initial Cure	Density	Symbol
16	Restricted Foamed	1 Hr. @ R.T.	2.62 #/ft.³	⊙

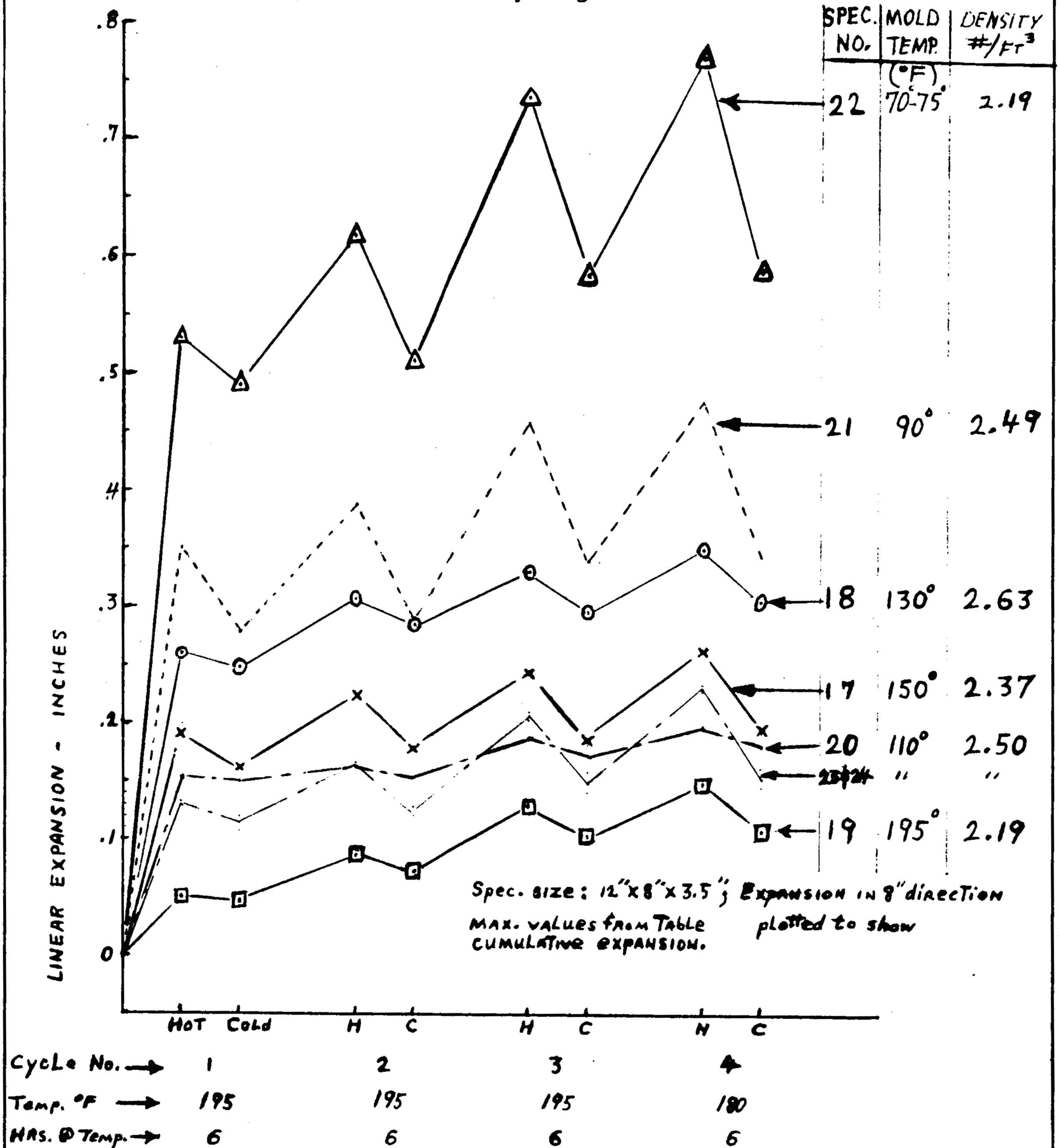
Spec. size: 12"x8"x3.5"; Expansion in 8" direction.
Max. values from Table plotted to show cumulative expansion.



CYCLE NO. →	1	2	3	4
Temp. °F →	150	150	150	195
Hrs. @ Temp. →	5	6	6	6

CALC			REVISED	DATE	BMS 8-38 Type I, Gr "FR" Rigid Foam. Linear Expansion of 8" THK. Spec. Vs Elevated Temp. Cycling. PHASE Ia Figure 8	T5-6556-1
CHECK						
APR						
APR					THE BOEING COMPANY	PAGE 38

Linear Expansion of 8" THK. Foam
Spec. Vs. Thermal Cycling



NOTE: ALL SPECIMENS WERE RESTRICTED FOAMED & CURED 24 HRS @ R.T. BEFORE REMOVING LID.

	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					Effect of Mold Temperature on Linear Expansion of BMS 8-38, Type I GR, "FR" Foam FIGURE 9, Phase II	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV. 12-64

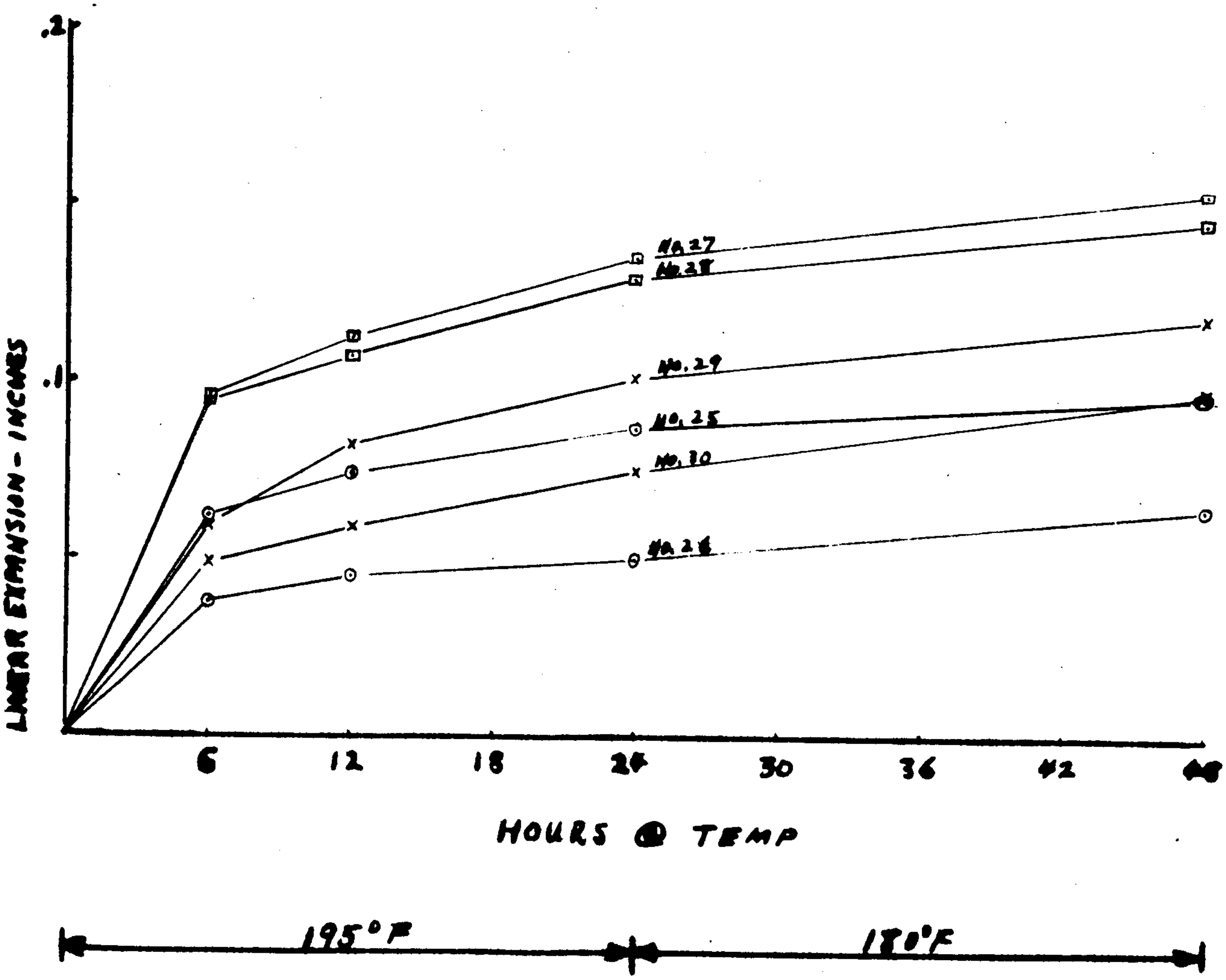
NOTES: (1) Spec size: 12" x 8" x 3.5"; Expansion in 8" direction.

(2) Max. values from Table plotted to show cumulative expansion.

(3) Initial cure (applicable to all specimens): 28 Hr. @ 150°F + 24 Hr. @ R.T., with cover on.

(4) Other specimen data:

Symbol	Spec No.	Initial Mold Temp.	Final Density #/Ft³
⊙	25 & 26	195°F	2.31 & 2.10, Respectively.
⊡	27 & 28	150°F	2.30 & 2.32, "
X	29 & 30	220°F	2.31 & 2.29, "



	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					Effect of Initial Mold Temp. & Initial Cure Cycle on Post Expansion - BMS 8-38, Type I, G_R "FR" Foam	
CHECK					Figure 10, Phase Ia	
APPD.						
APPD.						

U3 4013 8000 REV. 12-64

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REV LTR

BOEING NO. T5-6556-13

SH. 40

Notes: (1) Max. values from Table plotted to show cumulative expansion.

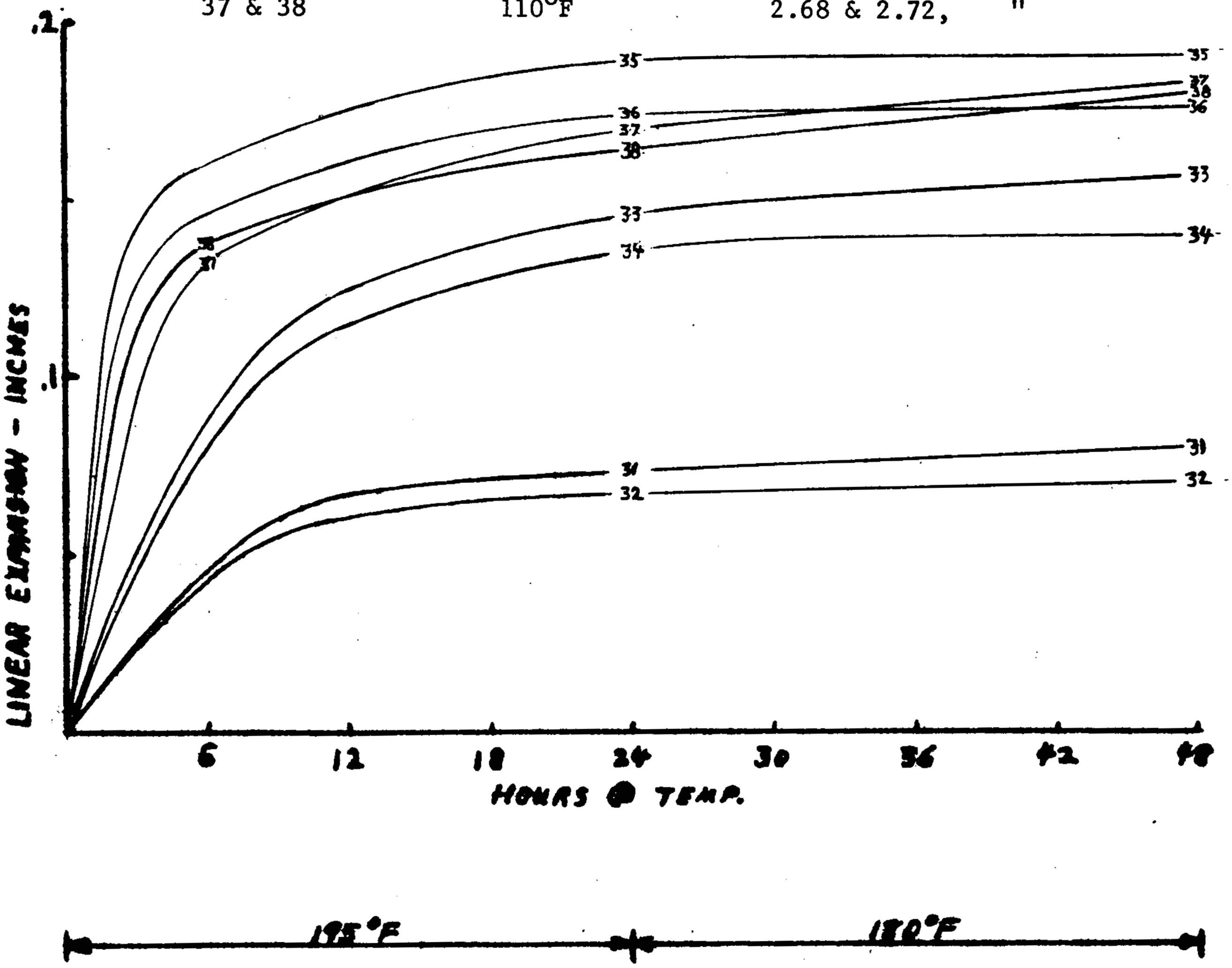
(2) Spec. size: 12" x 8" x 3.5"; Expansion in 8" direction.

(3) Initial cure (specimens 31-36): 8 Hr. @ 150°F + 24 Hr. @ R.T., with cover on.

( ) Initial (specimens 37 & 38): 8 Hr. @ 110°F + 24 Hr. @ R.T., with cover on.

(4) Other Spec. Data:

Spec. No.	Initial Mold Temp.	Final Density (#/Ft^3)
31 & 32	195°F	2.37 & 2.40, Respect.
33 & 34	150°F	2.45 & 2.52, "
35 & 36	110°F	2.37 & 2.42, "
37 & 38	110°F	2.68 & 2.72, "



	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					Effect of Initial Mold Temp. & Initial Cure Cycle on Post Expansion - BMS 8-38, Type I, G_R "FR" Foam. Figure 11, Phase Ia	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV. 12-64

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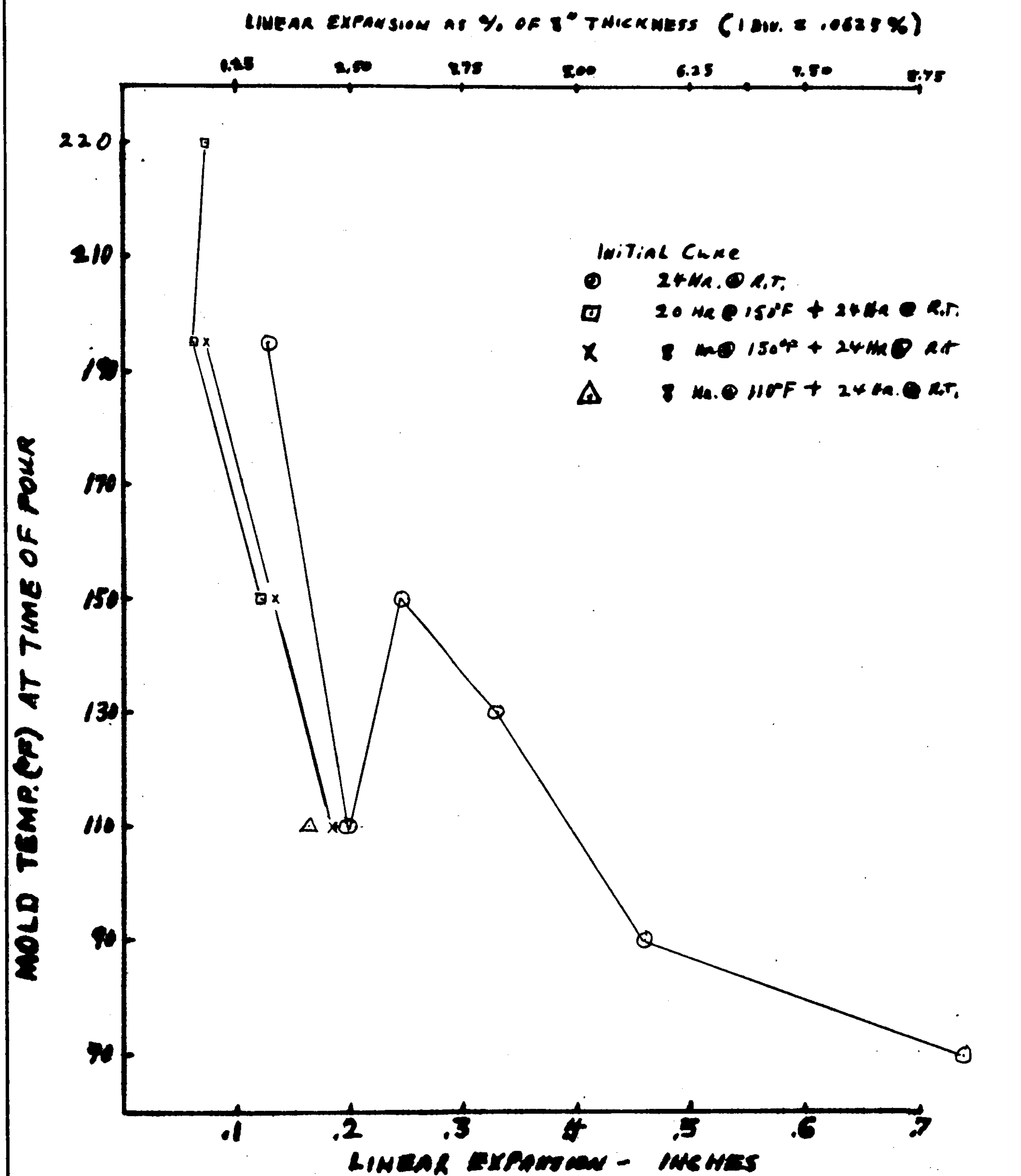
REV LTR

BOEING NO. T5-6556-13



	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					Linear Expansion vs. Mold Temperature plus Elevated Initial Cure - BMS 8-38 Type I, GR "FR" Foam	
CHECK						
APPD.						
APPD.					Figure 12, Phase Ia	

U3 4013 8000 REV. 12-64

REV LTR

BOEING NO. T5-6556-13

SH. 42

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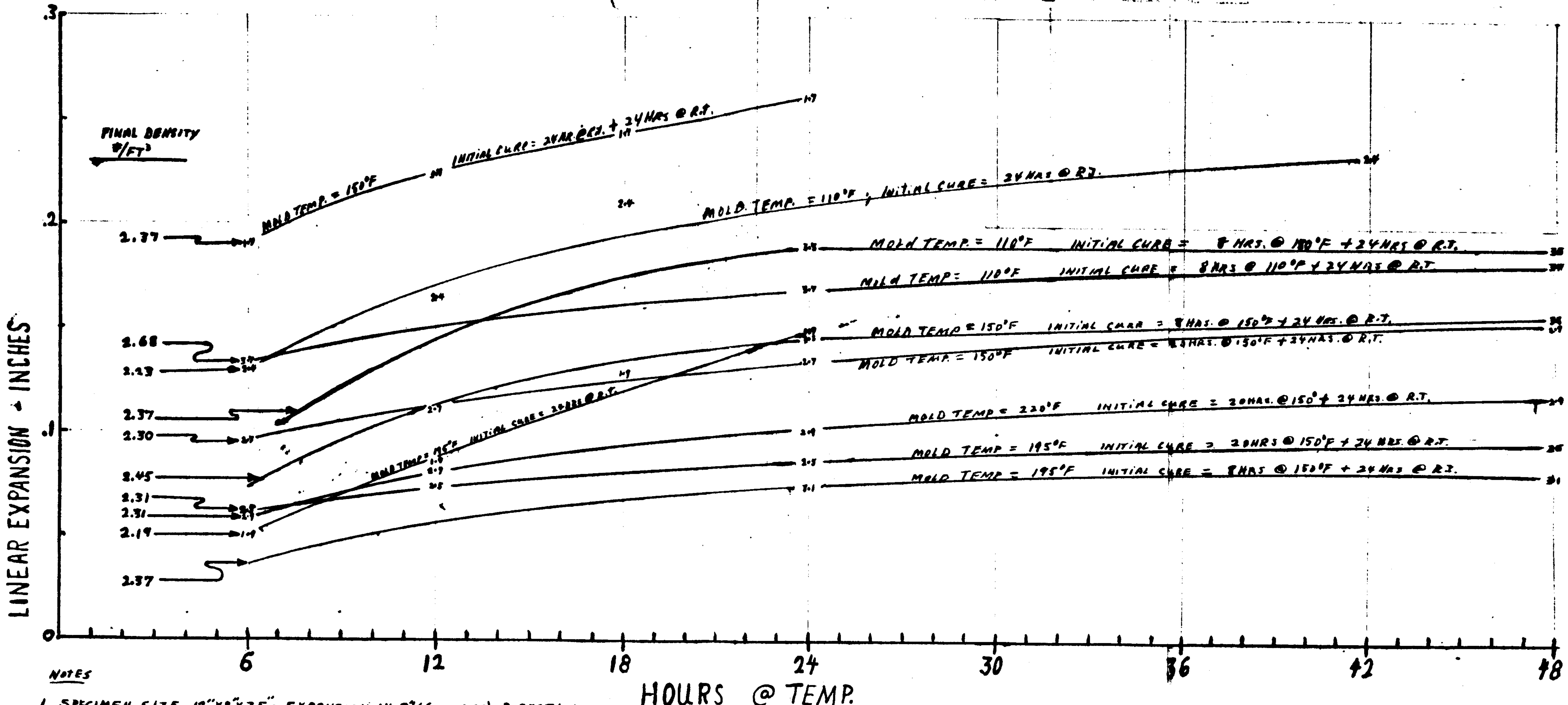


NOTES

1. SPECIMEN SIZE 12"X8"X3.5"; EXPANSION IN 8" (foam rise) DIRECTION
2. MOLD MADE FROM .1" THICK (NOMINAL) ALUMINUM ALLOY
3. MAXIMUM VALUES FROM TABLE PLOTTED TO SHOW CUMULATIVE EXPANSION
4. THE ABOVE CURVES REPRESENT THE WORST CASE (where duplicate tests were run) OF THE BEST CURE CYCLES.
5. ALL CURVES START FROM "0". THIS PART WAS OMITTED TO AVOID CLUTTERING.
6. SPEC. NOS 17 & 19 WERE @ 195°F FOR 18 HRS PLUS 6 HRS. @ 180°F.
   " NO. 24 WAS " " " 24 " " " "
   ALL OTHER SPEC. WERE @ 195°F FOR 24 HRS PLUS 24 HRS. @ 180°F.

CALC			REVISED	DATE	EVALUATION OF VARIOUS CURE CYCLES FOR BMS 8-38 , TYPE I, GR FR RIGID FOAM	
CHECK					FIGURE 13 - Phase Ia	
APR					THE BOEING COMPANY	PAGE
APR						

FOAM Density Vs Specimen No.

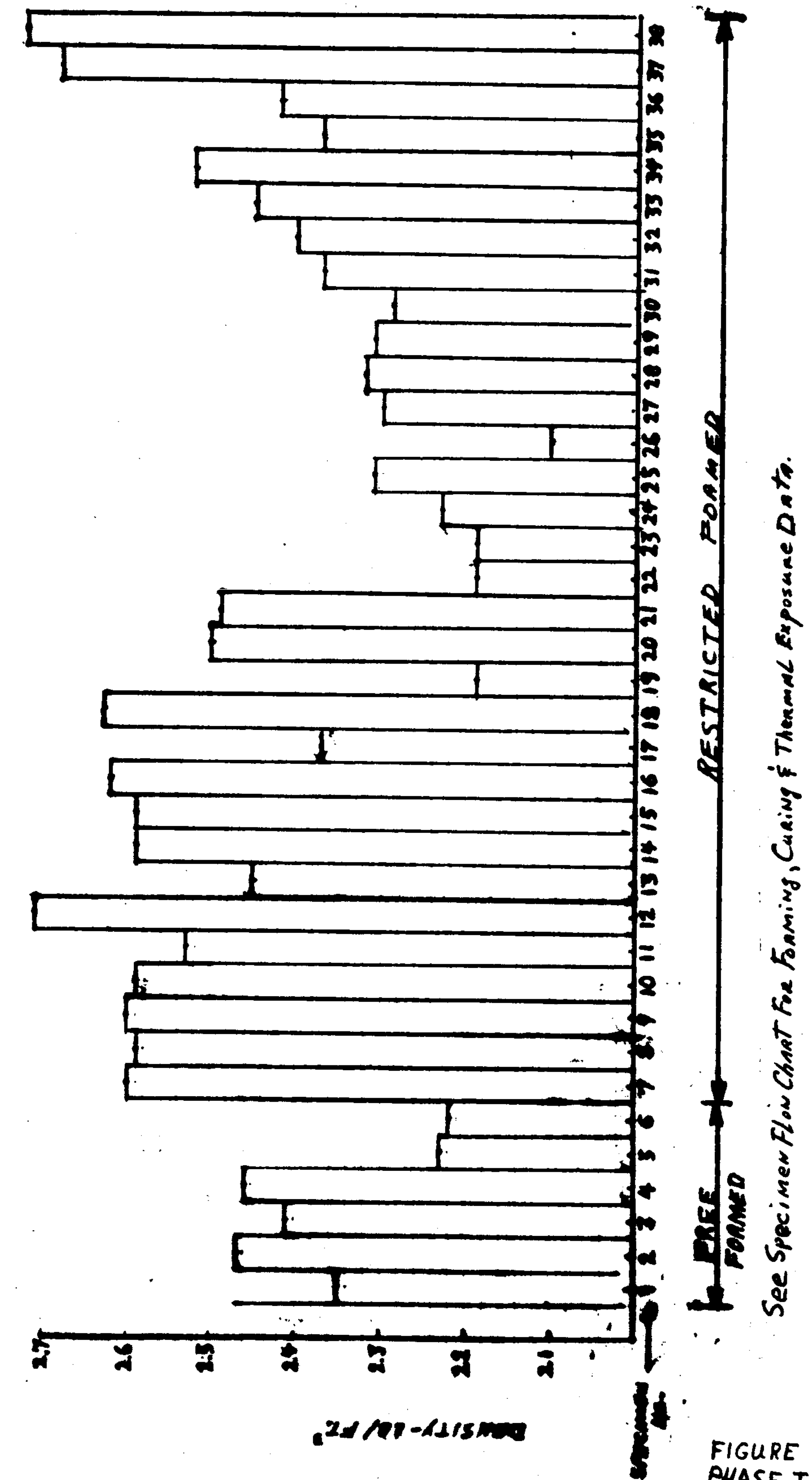


FIGURE 14, PHASE Ia

5.2 PHASE Ib

5.2.1 Objective

To compare the thermal stability of similarly processed Stafoam AA1802 and Nopco B610 rigid polyurethane foam materials.

5.2.2 Test Procedure

Four 8" x 4" x 3.5" aluminum molds plus covers were prepared (two for each foam material). Two thermocouples were installed in each mold; located 1" and 4" from the bottom.

The materials were mixed per manufacturer's instructions, poured into room temperature molds and cured at room temperature (with covers on) for 24 hours. Peak exotherm temperatures were monitored during foaming.

The linear expansion was monitored with electrical deflection transducers throughout the oven cycle, which was 195 $\pm$ 10°F for 36 hours. The oven was at room temperature initially but reached the test temperature in approximately $1\frac{1}{2}$ hours. The foam specimens stabilized at the test temperature after 2 hours.

5.2.3 Test Results

5.2.3.1 Presentation of Data

Table I shows the inches of linear expansion as determined with electrical deflection transducers. Figure 1 is a graph of this data. Figures 2 and 3 (photographs) show the relative expansion of the two materials.

5.2.3.2 Expansion

The Stafoam expanded 0.30" and the Nopco expanded .075" over a 36-hour period at 195 $\pm$ 10°F. Percentage wise, this amounts to about 4% and 1%, respectively.

5.2.3.3 Exothermic Temperature

The maximum exothermic temperature of the Nopco was 89° higher than that of the Stafoam. Duplicate Nopco foam blocks showed 260° and 275°F near the geometric center; corresponding Stafoam temperatures were 171°F and 186°F.

Thermocouples located 1" from the bottom of the foam blocks showed 119°F and 127°F for Stafoam; this compares to 200°F and 216°F for Nopco.

5.2.3.4 Foam Density

The density of the restricted foamed Stafoam was 2.5 $\#/ft^3$. The density of the Nopco was 8.3 $\#/ft^3$.

5.2.4 Conclusions

When foamed and cured at room temperature, the Nopco has greater dimensional stability when subjected to subsequent elevated temperature exposures.

The Nopco generates more heat during foaming.

The density of the Nopco foam is 3 to 4 times that of the Stafoam.

FOAM BOX DEFLECTION AND TEMPERATURE DATA

FOAM BOX NOMENCLATURE Test Condition 195°F

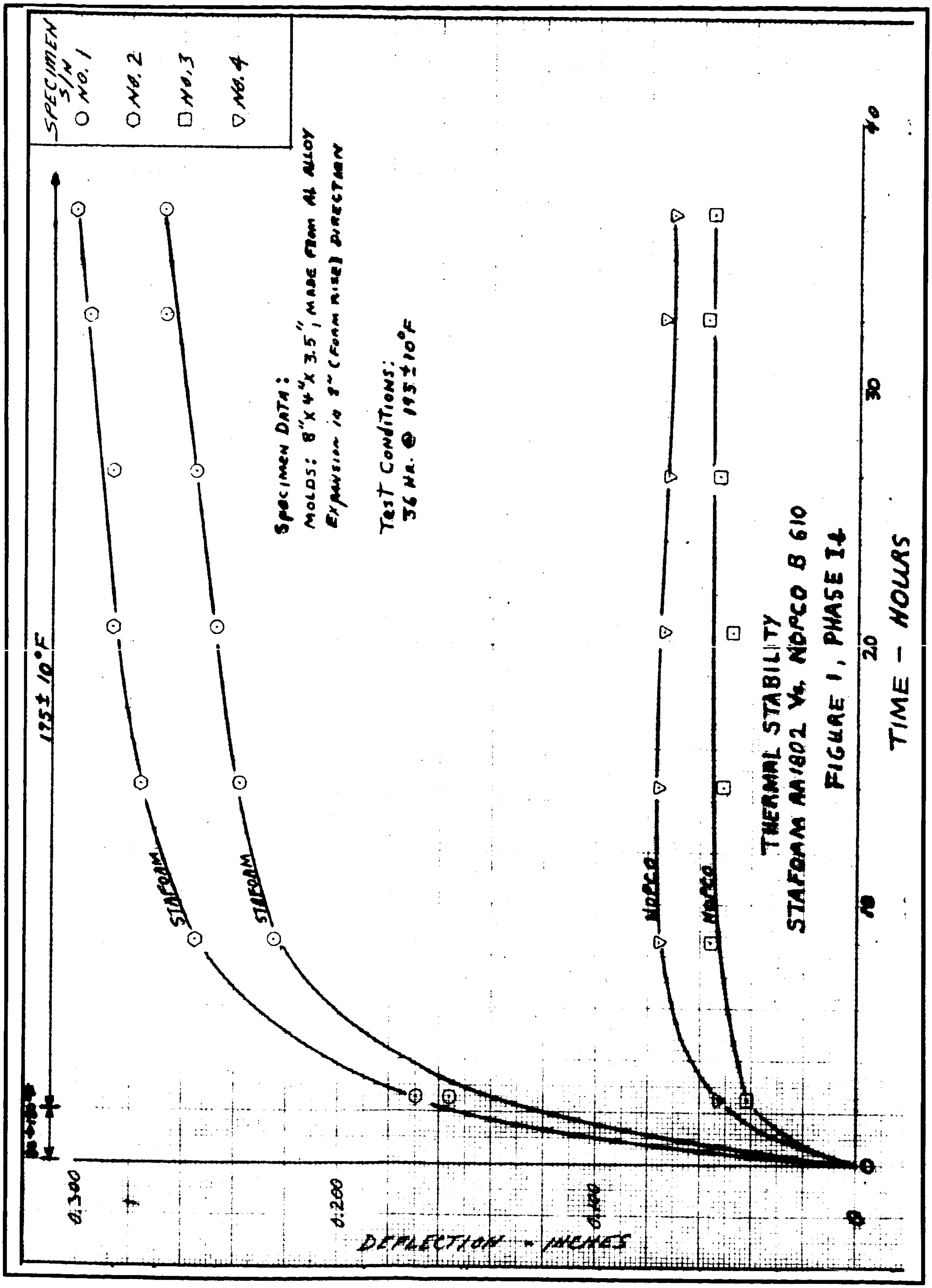
FOAM BOX SERIAL NUMBERS 1, 2, 3, 4

DATE 3/21/67

TIME	DEFLECTION IN INCHES								TEMPERATURE °F								REMARKS
MIN/HRS.	D1	D2	D3	D4					TC (1C)	TC (1E)	TC (2C)	TC (2E)	TC (3C)	TC (3E)	TC (4C)	TC (4E)	
0									81	80	80	80	80	80	80	80	NO DEFLECTION DATA - RECORDER OFF
15	0	0	0	0					88	96	90	95	87	92	88	94	
30																	NO DEFLECTION DATA - RECORDER OFF
45			0	.01					114	125	118	124	108	119	112	120	NO DATA ON D1 & D2 - POLARITY REVERSED
60			.01	.01					130	140	133	139	122	134	125	135	NO DATA ON D1 & D2 - POLARITY REVERSED
75			.02	.02					146	155	149	154	135	149	139	150	NO DATA ON D1 & D2 - POLARITY REVERSED
90			.02	.03					158	168	162	167	150	160	152	161	NO DATA ON D1 & D2 - POLARITY REVERSED
105	.12	.12	.03	.04					170	178	174	178	163	173	165	173	
120	.14	.16	.04	.05					182	190	185	189	174	184	176	185	
135	.16	.18	.04	.05					190	195	193	194	183	191	185	190	
150	.18	.20	.04	.06					193	194	194	195	188	193	188	193	Thermocouples (TC)
165	.19	.21	.04	.06					194	195	195	195	192	194	192	194	embedded in Foam.
180	.19	.22	.05	.07					196	196	196	196	193	195	194	195	
195	.20	.23	.05	.07					196	196	196	196	195	195	195	195	Location of T.C:
210	.20	.23	.05	.07					195	195	196	195	194	195	195	195	Stafoam: 1C, 1E, 2C, & 2E
225	.20	.24	.05	.07					195	195	196	195	195	195	195	195	Nopco: 3C, 3E, 4C, & 4E
240	.21	.24	.05	.07					196	195	195	195	195	195	195	195	
8 HRS	.23	.25	.05	.08					197	197	197	197	197	198	198	197	Location of Deflection Indicators:
12 HRS	.23	.27	.05	.08					198	198	198	198	197	197	198	198	Stafoam: D1 & D2
16 HRS	.24	.27	.05	.08					200	200	201	201	200	200	201	201	Nopco: D3 & D4
20 HRS	.24	.28	.05	.07					198	198	199	199	198	198	199	199	
24 HRS	.25	.29	.05	.07					199	199	200	201	199	199	201	201	
28 HRS	.25	.29	.05	.07					199	200	201	201	199	200	201	201	
32 HRS	.26	.29	.06	.07					202	202	203	203	202	202	203	203	
36 HRS	.26	.29	.06	.07					200	200	201	201	200	200	202	202	
FULL SCALE DEFLECTION	0.75	0.75	0.75	0.75													Accuracy: ±5% of full scale.
			TIME OF FIRST DEFLECTION														

Determination of Dimensional Stability of Cured BMS 8-38, Type I, Gr. "FR" Foam and Nopco B 610 Foam, Phase Ib, Table I

REV. SYM. ____



SPECIMEN S/N
NO. 1
NO. 2
NO. 3
NO. 4
SPECIMEN DATA:
MOLDS: 8" X 4" X 3.5"; MADE FROM AL ALLOY
EXPANSION IN 8" (FOAM RISE) DIRECTION
TEST CONDITIONS:
36 HR. @ 195±10°F
195± 10°F
STAFOAM
STAFOAM
NOPCO
NOPCO
THERMAL STABILITY
STAFOAM AA1802 Vs. NOPCO B 610
FIGURE 1, PHASE I4
TIME - HOURS
DEFLECTION - INCHES
0.300
0.200
0.100
0
10
20
30
40

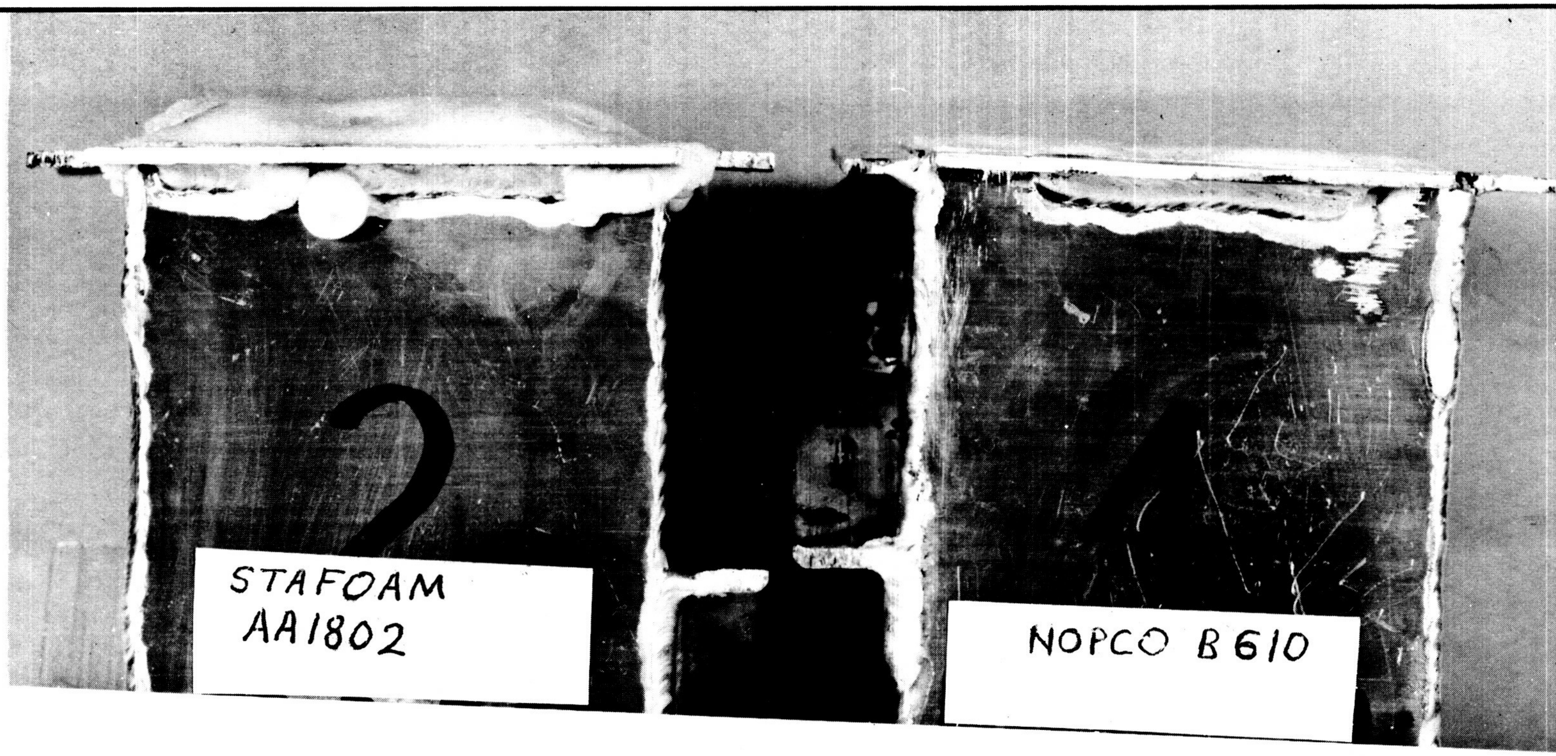


FIGURE 2 - PHASE I b

After 36 Hrs. @ 195^{o}F

Comparison of the Thermal Dimensional
Stability of Stafoam AA1802 & Nopco B610
Rigid Polyurethane Foams

FIGURE 3 - PHASE I-e

After 36 Hrs. @ 195^{O}F

Comparison of the Thermal Dimensional Stability of BMS 8-38 Type I, Gr. "FR" (Stafoam AA1802) & Nopco B610 Rigid Polurethane Foams

5.3 PHASE IIa

5.3.1 Objective

To determine the effects of post foam expansion on electrical continuity and on original dimensions of assembled distributors.

5.3.2 Identity of Distributors Tested

No. 1 "Sequence and Control", 60B62028-7A, S/N 0000011, Mfg. 9/21/66

History: Previously subjected to Boeing reliability tests (BRT) but not exposed to elevated temperatures that effected foam expansion. One foam wall of the printed circuit (p.c.) card cavity had been shaved back to meet drawing dimensions. Figure 2a shows this distributor before heating.

No. 2 "Thrust OK", 60B62295-5A, S/N 0000017, Mfg. 6/6/66

History: Previously subjected to BRT but not exposed to elevated temperatures that effected foam expansion. None of the foam surfaces had been trimmed. Figure 3a shows this distributor before heating.

No. 3 "Timer Distributor", 60B62030-1, S/N 0000001, Mfg. 8/4/65

History: Previously subjected to Boeing qualification tests (BQT) during which the distributor was exposed to a 250°F oven temperature (while being intentionally subjected to 180°F for 1 hour) due to a malfunction of oven controls. The temperature was reduced to 122°F and the pressure reduced to 2 psig. The exact time at these conditions was not recorded. All foam walls, except one relay wall, had been trimmed back to meet drawing dimensions. Cracks in the foam surface were evident - probably caused by the high temperature exposure. Figure 4a shows this distributor before heating per this test.

No. 4 "Sequence and Control", 60B62028-1, S/N 0000003, Mfg. 8/6/65

History: Previously subjected to BQT but not exposed to elevated temperature that effected foam expansion. None of the foam surfaces had been trimmed. Figure 5a shows this distributor before heating.

5.3.3 Test Procedure

5.3.3.1 Test Conditions

Distributors No. 1 and No. 2 were subjected to a nominal 180 ± 5°F oven cycle for 22.5 hours. No. 3 and No. 4 were subjected for 16 hours. The assembled distributors were placed in room temperature ovens and stabilized at 180 ± 5°F; the exact time required for each distributor to reach temperature is shown in Tables I thru IV.

5.3.3.2 Measurements

The dimensional changes, caused by the expanding foam, were monitored with electrical deflection indicators (EDI) at points described in Table I, which is typical for all distributors. (Figures 1a, 1b, and 1c show a typical setup of the test apparatus.) In addition, dimensional changes were also determined, manually, at the points described in Section 5.3.3.2.1. Effects of the expanded foam on electrical continuity were determined with a Bendix Analyzer. The time required for the foam temperature to stabilize was determined with thermocouples embedded in the foam and monitored with a time-temperature recorder.

5.3.3.2.1 Equipment Used and Points Measured Manually

Measuring Equipment

a. Level table for holding specimen and measuring equipment.

b. Level blocks for leveling specimen.

c. Dial indicator for horizontal measurements.

d. Inside micrometer for vertical measurements.

e. Fixture for holding dial indicator in fixed position.

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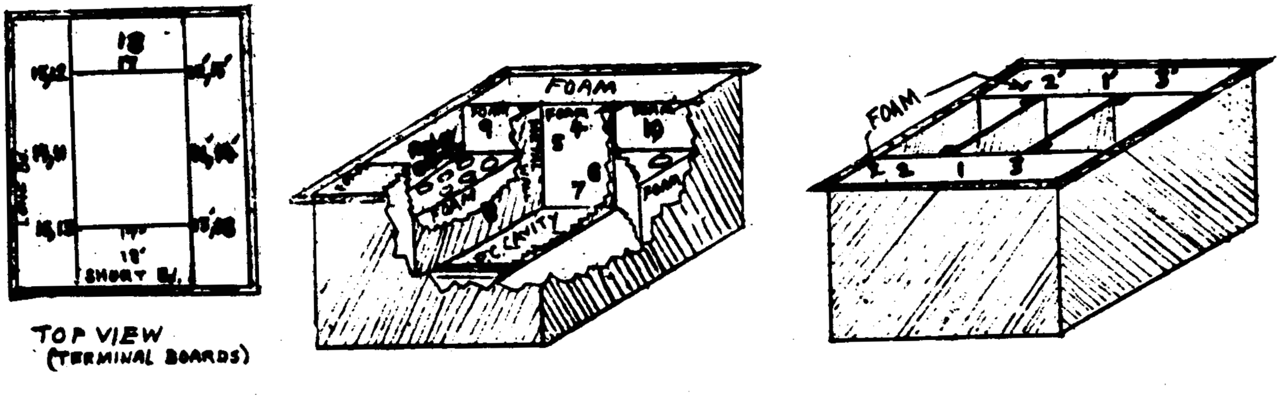
5.3.3.2.1 (Continued)

Nominal Location of Points Measured (see sketches below):

Point	Location
1 & 1'	Top center of foam masses located perpendicular to ends of p.c. cavity.
2, 3, & 2', 3'	Foam surface 3" each side of points 1 & 1'.
4, 5, 6, & 7	Distance between opposite points on foam wall of p.c. cavity. Points located as follows:
4	Vertical center line, 1 1/4" from top
5	1.5" from vertical center line and 1.5" from top
6	1.5" from vertical center line and 3" from top
7	Vertical center line, 4" from top
8	Distance between opposite points on metal walls of p.c. cavity. Points located mid-distance of long axis 2" from bottom.
9 & 10	Distance between opposite points on foam walls of relay cavities. Points located at approximate geometric center of foam walls.
11 & 11'	Long terminal boards, mid-distance of long axis along inside edge.
12, 13, & 12', 13'	Long terminal boards, 3" each side of points 11 & 11' along inside edge.
14 & 14'	Long terminal boards, approximate geometric center
15, 16, & 15', 16'	Long terminal boards, 3" each side of points 14 & 14' along long axis
17 & 17'	Short terminal boards, mid-point of long axis along inside edge
18 & 18'	Short terminal boards, approximate geometric center.

LOCATION OF POINT MEASURED MANUALLY



5.3.4 <u>Test Results</u>

5.3.4.1 Presentation of Data

Dimensional changes monitored with EDI are tabulated in Tables I thru IV. Changes determined manually are shown in Tables V-VIII. Figures 2a thru 5c show the various distributors before and after heating.

5.3.4.2 Effects of Foam Expansion on Electrical Continuity

Circuitry checks with a Bendix Analyzer before and after heating showed no evidence of open circuits in any of the four distributors.

5.3.4.3 Effects of Foam Expansion on Original Dimensions

The major expansion took place in the unconfined areas which were the vertical foam walls of the p.c. card cavity and the relay cavities. Figures 2b, 2c, 3b, 4b, 5b, and 5c show the various distributors after heating.

The maximum expansion measured on a single foam wall was .60", in distributor No. 1. The foam walls of distributors 2 and 4 showed similar, though somewhat less expansion. Distributor No. 3 showed very little expansion in this area, the reason being attributed to its thermal history (Section 5.3.2.).

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5.3.4.3 (Continued)

Large air pockets were formed, as shown in Figures 2c and 5c, behind the preformed dams. In areas where the outer surface of these dams had been removed (see history of the various distributors, Section 5.3.2) the permeability was apparently increased, resulting in somewhat less expansion. However, complete removal of these dams (Phase IIIc) did not eliminate all the foam expansion.

The maximum expansion or deflection measured on the terminal board side of any of the four distributors was .08". Distributors 3 and 4 even showed evidence of negative deflection as determined manually - Tables VII and VIII.

5.3.4.4 Effect of Foam Expansion on the "Union Switch Relay" Holes

The foam expanded considerably into the vacant holes making trimming necessary in order to insert relays. Distributors 3 and 4 had relays installed prior to heating. In these cases the expanding foam did not adversely affect the holes. This is best shown by distributor No. 4 - Figures 5a, 5b, and 5c. The relays were easy to remove, except for those located on the ends where the foam had expanded against them.

5.3.4.5 Effects of Foam Expansion on Metal Walls of P.C. Card Cavity

The foam expansion did not significantly effect the distance between these walls as shown by both the EDI and the manual measurements. In addition the relative ease with which p.c. cards could be inserted before and after heating was unchanged.

5.3.4.6 Time Required for Foam Expansion to Stabilize

Results from Tables I-IV show that foam expansion stabilized in approximately 3 1/2 to 12 hours (depending on the distributor) from the time the oven was turned on. (Later studies have shown that the oven used takes about 1 1/2 hours to go from ambient to 180 $\pm$ 5° F.) Distributor No. 1 showed no more expansion after 12 hours. Nos. 2 and 4 had stabilized after 8 hours. No. 3 stabilized after 3 1/2 hours, but this fast stabilization is attributed to its thermal history (Section 5.3.2). In all cases 50% or more of the total expansion was effected by the time the foam reached test temperature, which took 2 to 3 hours starting from ambient.

5.3.5 Summary of Results

Out of several thousand circuits checked there was no evidence of broken wires caused by foam expansion.

The maximum degree of outward bulging measured on the terminal board side of any of the four distributors tested was less than 0.1 inches.

Expansion into the p.c. cards appeared to be the only area where functional damage might occur. Phase IIb was initiated to ascertain this.

DISTRIBUTOR DEFLECTION AND TEMPERATURE DATA

DISTRIBUTOR NOMENCLATURE Sequence and Control (BRT) DISTRIBUTOR SERIAL NUMBER 200001 Mfg 9-2166 DATE 3/15/67

TIME MIN/HRS	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	T.C. 1	T.C. 2	T.C. 3
	DEFLECTION IN INCHES												TEMPERATURE °F		
0	0	0	0	0	0	0	0	-0.01	0	0	-0.01	0	70	70	70
15	0.01	0	-0.01	0	0	0	0	-0.01	0	0	-0.01	-0.01	70	70	70
30	0	0	0	0	0	0	0	-0.01	0	0	-0.01	0	87	80	80
45	0	-0.01	-0.01	0	0	-0.01	0	-0.01	0	0	-0.01	0	102	95	94
60	0	0	0	0	0	0	0	0	0	0	-0.01	0	116	110	108
75	0	0	0	0	0	0	0	0	0	0	-0.01	0.02	133	126	125
90	0	0	0	0	-0.01	0	0	0	0.01	-0.01	-0.01	0.07	142	134	133
105	0.01	0.01	0	0.01	0	0	0	0.01	0.04	0	-0.01	0.16	155	148	147
120	0.02	0.01	0	0.01	0	0	0	0	0.09	0	-0.01	0.27	163	158	157
135	0.03	0.02	0.01	0.01	0	0.01	0	0.02	0.12	0	-0.01	0.36	167	165	164
150	0.03	0.02	0.01	0.02	0.01	0	0.01	0.02	0.14	0	-0.01	0.39	172	170	170
165	0.03	0.03	0	0.02	0.02	0.01	0	0.02	0.16	0	-0.01	0.41	174	173	173
180	0.05	0.03	0.01	0.02	0.02	0.01	0.01	0.03	0.17	0	-0.01	0.50	176	175	175
195	0.05	0.03	0.01	0.02	0.02	0.01	0.02	0.03	0.19	0	-0.01	0.52	175	175	175
210	0.06	0.03	0.02	0.02	0.02	0.01	0.01	0.03	0.19	0	-0.01	0.55	175	175	175
225	0.06	0.03	0.01	0.02	0.02	0.01	0.01	0.03	0.20	0	-0.01	0.56	177	177	177
240	0.06	0.03	0.01	0.02	0.02	0.01	0.01	0.04	0.21	0	-0.01	0.57	176	176	176
8 HRS	0.07	0.03	0.01	0.03	0.03	0.02	0.02	004	0.26	0	-0.01	0.60	177	177	177
12 HRS	0.06	0.02	0.01	0.04	0.03	0.02	0.02	0.03	0.34	0	-0.01	0.39	177	177	178
16 HRS	0.07	0.02	0.01	0.04	0.02	0.01	0.01	0.04	0.34	-0.01	-0.02	0.53	178	178	179
20 HRS	0.07	0.03	0.01	0.03	0.02	0.01	0.01	0.04	0.34	0	-0.01	0.60	179	179	179
22.5 HRS	0.06	0.02	0.01	0.03	0.02	0.01	0.01	0.03	0.34	-0.01	-0.02	0.59	175	176	176
FULL SCALE DEFLECTION	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.5	0.5	0.75			

TIME OF FIRST DEFLECTION

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
91 min. 27 sec.	77 min 6 sec.	62 min 45 sec.	92 min. 48 sec.	100 min. 2 sec.	101 min. 42 sec.	62 min. 45 sec.	53 min. 25 sec.	76 min. 15 sec.	21 min. 18 sec.	51 min. 10 sec.	60 min. 48 sec.

REMARKS

Location of Points Monitored:

D_1 & D_5 - Inside edge of long terminal boards; mid-distance of long axis.

D_2, D_4, D_6, & D_8 - Long terminal boards; 3" from each end, mid-distance of short axis.

D_3 & D_7 - Short terminal boards; inside edge; mid-distance of long axis.

D_9 & D_{12} - Foam walls of p.c. card cavity; Approximate geometric center

D_{10} & D_{11} - Metal walls of p.c. card cavity; 2" from bottom, mid-distance of long axis.

Location of Thermal Couples:

No. 1 Top side of terminal board

No. 2 & No. 3 Embedded about 3" in foam.

Accuracy: ± 5% of Full Scale Deflection.

Determination of Dimensional Stability of Cured BMS 8-38, Type I, Gr. "FR" Foam - Test Distributor No. 1, Phase IIa, Table I

REV. SYM. ____

DISTRIBUTOR DEFLECTION AND TEMPERATURE DATA

DISTRIBUTOR NOMENCLATURE Thrust OK (BRT) DISTRIBUTOR SERIAL NUMBER 000017 Mfg. 6-6-66 DATE 3/15/67

TIME	DEFLECTION IN INCHES													TEMPERATURE °F			REMARKS
MIN/HRS	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D	T.C. 1	T.C. 2	T.C. 3	
0	0	0	0	0	0	0	0	0	0	0	0	-.01		70	70	70	See table I Phase IIa
15	0	0	0	0	0	0	0	0	0	0	0	-.01		80	70	70	for location of points
30	0	0	0	0	0	0	0	0	0	0	0	-.01		95	82	80	monitored
45	0	0	0	0	0	0	0	0	0	0	0	-.01		112	96	93	
60	0	0	0	0	0	0	0	0	0	.01	0	0		126	114	110	
75	0	.01	.01	.01	0	0	0	.01	0	-.01	0	0		144	130	125	
90	.01	.02	.01	.01	.01	.01	0	.01	.02	-.01	-.01	.01		152	137	134	
105	.01	.02	.01	.02	.02	.01	0	.01	.06	-.01	-.01	.01		163	163	148	
120	.01	.02	.01	.02	.02	.01	0	.02	.10	-.01	-.01	.11		167	163	158	
135	.02	.02	.01	.03	.03	.02	.01	.02	.14	-.01	-.01	.14		172	167	165	
150	.02	.03	.02	.03	.03	.02	.01	.02	.18	-.01	-.01	.18		173	170	170	
165	.02	.03	.02	.03	.03	.03	.01	.03	.21	-.01	-.01	.21		176	175	173	
180	.02	.03	.02	.03	.04	.02	.02	.03	.22	-.01	-.01	.24		178	177	177	
195	.02	.03	.02	.03	.04	.02	.02	.03	.24	-.01	-.01	.25		176	176	176	
210	.02	.03	.02	.03	.05	.03	.02	.03	.25	-.01	-.01	.28		176	176	176	
225	.02	.03	.02	.03	.05	.03	.02	.03	.27	-.01	-.01	.30		177	177	177	
240	.02	.03	.02	.03	.05	.03	.02	.03	.27	-.01	-.01	.33		177	177	177	
8 HRS	.02	.03	.02	.03	.05	.03	.02	.03	.30	-.01	-.01	.46		177	179	179	
12 HRS	.02	.03	.02	.03	.06	.03	.03	.03	.30	-.01	-.01	.46		177	179	179	
16 HRS	.02	.03	.02	.03	.06	.04	.03	.03	.31	-.01	-.01	.47		178	180	180	
20 HRS	.02	.03	.03	.03	.06	.04	.03	.03	.30	-.01	-.01	.47		180	180	180	
22.5 HRS	.02	.03	.02	.03	.06	.03	.03	.03	.30	-.01	-.01	.48		175	175	175	
FULL SCALE DEFLECTION	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.5	0.5	0.75					ACCURACY: ±5% of full
	TIME OF FIRST DEFLECTION																SCALE
	D	D	D	D	D	D	D	D	D	D	D	D	D				
	68 Min	38 Min	34 Min.	41 Min	23 Min	68 Min	58 Min.	65 Min	84 Min	29 Min	30 Min	53 Min					
	42 SEC	44 SEC.	0 SEC.	15 SEC.	17 SEC.	15 SEC.	11 SEC.	26 SEC.	42 SEC.	35 SEC.	10 SEC.	37 SEC.					

Determination of Dimensional Stability of Cured BMS 8-38, Type I, Gr. "FR" Foam - Test Distributor No. 2, Phase IIa, Table II

REV. SYM. ______

DISTRIBUTOR DEFLECTION AND TEMPERATURE DATA

DISTRIBUTOR NOMENCLATURE Timer (BQT)

DISTRIBUTOR SERIAL NUMBER 0000001 Mfg. 8-465

DATE 3/15/67

TIME	DEFLECTION IN INCHES												TEMPERATURE °F			REMARKS
MIN/HRS	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	T.C.1	T.C.2	T.C.3	See Table I, Phase IIa
0	0	0	0	0	0	0	0	0	-0.01	-0.01	0	0	72	72	72	for location of points monitored
15	0	0	0	0	0	0	0	0	-0.01	-0.01	0	0	72	72	72	
30	0	0	0	0	0	0	0	0	-0.01	-0.01	0	0	87	82	80	
45	0	0	0	0	0	0	0	0	-0.01	-0.01	0	0	104	93	92	
60	0	0	0	0	0	0	0	0	0	-0.01	0	0	115	107	103	
75	0	0	0	0	0	0	0	0	-0.01	-0.01	0	0	127	117	115	
90	0	0	0	0	0.01	0	0	0	-0.01	-0.01	0	0				TEMPERATURE RECORDER INOPERATIVE AT THIS POINT
105	0.01	0.00	0	0	0.01	0	0	0	0	-0.01	0	0.01	167	159	159	
120	0.01	0	0	0	0.02	0	0	0	0.02	-0.01	-0.01	0.02	171	166	166	
135	0.02	0.01	0	0.01	0.03	0.01	0	0	0.04	-0.02	0	0.03	178	177	177	
150	0.02	0.01	0	0.01	0.03	0.01	0	0	0.05	-0.02	-0.01	0.04	180	178	178	
165	0.03	0	0	0.01	0.03	0.01	0	0	0.05	-0.01	-0.01	0.04	180	178	178	
180	0.03	0.01	0	0.01	0.03	0.01	0	0	0.06	-0.01	-0.01	0.04	180	178	178	
195	0.03	0.01	0	0.01	0.03	0.01	0	0	0.06	-0.02	-0.01	0.05	180	179	179	
210	0.03	0.01	0	0.01	0.03	0	0	-0.01	0.07	-0.01	-0.01	0.05	180	180	180	
225	0.03	0.01	0	0.01	0.03	-0.01	0	0	0.07	-0.02	-0.01	0.05	180	180	180	
240	0.03	0.01	0	0.01	0.03	+0.01	0	0	0.07	-0.02	-0.01	0.04	180	180	180	
8 HRS	0.02	0.01	0	0.01	0.03	0.01	0	0.01	0.08	-0.01	-0.01	0.05	181	181	181	
12 HRS	0.02	0.01	0	0.02	0.03	0.01	0	0.01	0.08	-0.01	0	0.05	182	181	181	
16 HRS	0.01	0	0	0.01	0.02	0	0	0	0.07	-0.01	-0.01	0.06	123	145	145	OVEN TURNED OFF AT 15:36 HRS.
20 HRS																
Full Scale Deflection	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.0	0.5	0.5	1.0				Accuracy: ±5% of full scale

TIME OF FIRST DEFLECTION

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	REMARKS
93 min. 39 sec.	100 min. 54 sec.	—	128 min. 49 sec.	76 min. 3 sec.	105 min. 6 sec.	—	—	97 min. 51 sec.	61 min. 54 sec.	64 min. 18 sec.	94 min. 24 sec.	No Significant Deflection on D_3, D_7, and D_8

Determination of Dimensional Stability of Cured BMS 8-38, Type I, Gr. "FR" Foam - Test Distributor No. 3, Phase IIa. Table III

REV. SYM.

DISTRIBUTOR DEFLECTION AND TEMPERATURE DATA

DISTRIBUTOR NOMENCLATURE Sequence & Control (BGT)

DISTRIBUTOR SERIAL NUMBER 000003 Mfg 8665

DATE 3/15/67

TIME MIN/HRS	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	D 9	D 10	D 11	D 12	T.C. 1 (°F)	T.C. 2 (°F)	T.C. 3 (°F)	REMARKS
0	0	0	0	0	0	0	0	0	-.01	-.01	0	.01	72	72	72	See Table I, Phase IIa
15	0	0	0	0	0	0	0	0	-.01	0	0	.01	72	72	72	for Location of points monitored
30	0	0	0	0	0	0	0	0	-.01	0	0	.01	95	85	83	
45	0	0	-.01	0	-.01	0	0	0	-.01	-.01	-.01	0	107	98	96	
60	0	0	0	.01	0	0	0	0	-.01	-.01	-.01	.02	120	115	110	
75	0	.01	0	.02	.01	.01	0	.01	.04	-.01	-.01	.09	135	127	120	
90	.01	.01	0	.02	0	.01	0	.01	.19	-.01	-.01	.17				TEMPERATURE RECORDER INOPERATIVE AT THIS POINT
105	.02	.02	.01	.02	.02	.02	.01	.02	.36	-.01	-.01	.27	173	168	164	
120	.03	.03	.01	.02	.02	.03	.01	.02	.43	-.01	-.01	.33	179	173	175	
135	.05	.03	.02	.03	.03	.03	.01	.03	.48	-.01	-.01	.35	180	179	177	
150	.05	.03	.02	.03	.04	.03	.01	.03	.53	-.01	-.01	.39	180	180	180	
165	.05	.03	.02	.02	.03	.04	.02	.03	.53	0	-.01	.41	180	180	180	
180	.07	.03	.02	.02	.04	.07	.02	.03	.51	.01	0	.41	180	180	180	
195	.08	.04	.02	.02	.03	.07	.02	.02	.50	.02	0	.42	181	181	180	
210	.07	.03	.02	.02	.03	.06	.02	.02	.48	.01	0	.43	181	182	181	
225	.08	.03	.02	.02	.03	.07	.02	.02	.49	.01	0	.43	181	182	182	
240	.08	.03	.02	.02	.03	.07	.02	.02	.49	.01	0	.42	182	182	182	
8 HRS	.04	.02	.01	.01	.03	.02	.01	.02	.53	-.01	0	.46	182	182	182	
12 HRS													183	183	183	DEFLECTION RECORDER "B" INOPERATIVE AT THIS POINT
16 HRS	.03	0		0	.02	0	0	.01	.53	-.01	-.01	.46	119	137	144	OVEN TURNED OFF AT 15:34 HRS.
20 HRS																
HRS																
Full Scale Deflection	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.0	0.5	0.5	1.0				Accuracy: ±5% of full scale

TIME OF FIRST DEFLECTION

D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	D 9	D 10	D 11	D 12
67 Min. 20 Sec.	23 Min. 01 Sec.	25 Min. 27 Sec.	51 Min. 52 Sec.	62 Min. 43 Sec.	59 Min. 36 Sec.	73 Min. 09 Sec.	61 Min. 37 Sec.	67 Min. 43 Sec.	39 Min. 0 Sec.	28 Min. 15 Sec.	58 Min. 23 Sec.

Determination of Dimensional Stability of Cured BMS 8-38, Type I, Gr. "FR" Foam - Test Distributor No. 4, Phase IIa, Table IV

REV. SYM.

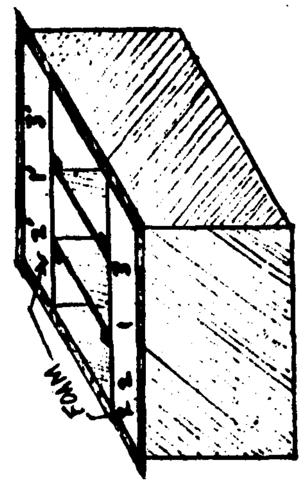
MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

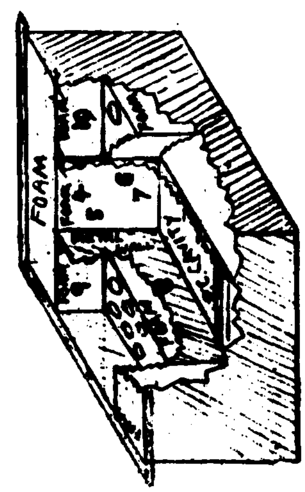
OVEN CYCLE

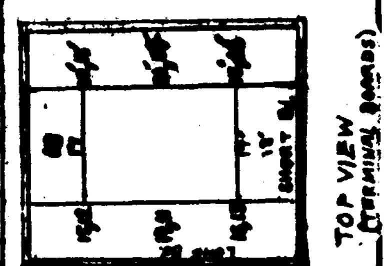
CYCLE: 180°F - 22.5 HR.

Points Measured	ΔL_i (INCHES)	ΔL_H	ΔL_{H-i}	ΔL_i	ΔL_H	ΔL_{H-i}
1	+.010	-.016	-.026			
1'	+.033	0	-.033			
2	+.011	-.006	-.017			
2'	+.018	+.001	-.017			
3	+.014	0	-.014			
3'	+.025	+.008	-.017			
4	7.032	6.475	-.557			
5	7.025	6.605	-.420			
6	7.080	6.590	-.490			
7	7.071	6.565	-.506			
8	3.813	3.800	-.013			
9	7.005	6.531	-.474			
10	6.960	6.441	-.519			
11						
11'	+.097	+.146	+.049			
12	+.084	+.186	+.002			
12'	+.097	+.174	+.017			
13	+.095	+.138	+.043			
13'						
14						
14'	+.097	+.131	+.034			
15	+.086	+.192	+.006			
15'	+.099	+.142	+.043			
16	+.085	+.1[illegible]	+.019			
16'	+.094	+.111	+.017			
17	+.100	+.101	+.001			
17'	+.094	+.099	+.005			
18	+.099	+.100	+.001			
18'	+.095	+.098	+.003			

Location of Points Measured







ΔL_i = Distance from a "zero point" or between 2 opposite points before thermal exposure

ΔL_H = Distance from "zero point" or between 2 opposite points after thermal exposure

ΔL_{H-i} = Dimensional change caused by thermal exposure

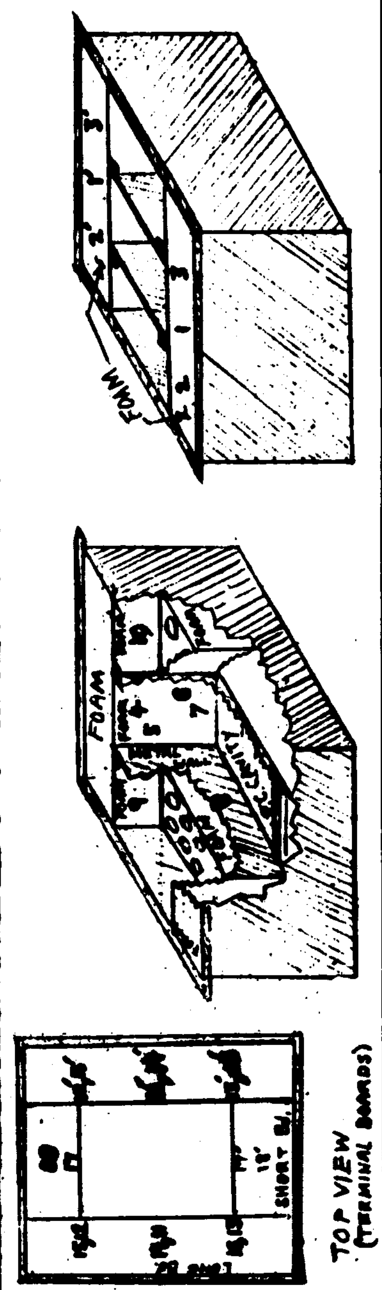
Manually Determined Dimensional Changes	Table V
Distr. No. 1 - Phase IIa "Seq. & Control", S/N 0000011	Phase [illegible]

MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

CYCLE: OVEN CYCLE 180°F - 22.5 Hr.

Points Measured	ΔL_i (INCHES)	ΔL_H	ΔL_{H-i}	ΔL_i	ΔL_H	ΔL_{H-i}
1	+.060	-.002	-.062			
1'	+.059	-.002	-.061			
2	+.037	+.001	-.036			
2'	+.024	+.001	-.023			
3	+.058	+.005	-.053			
3'	+.044	+.004	-.040			
4	6.904	6.150	-.754			
5	6.953	6.225	-.728			
6	6.973	6.010	-.983			
7	6.961	6.545	-.416			
8	3.756	3.755	-.001			
9	7.017	6.411	-.606			
10	7.029	6.390	-.639			
11	+.086	+.161	+.075			
11'	+.115	+.135	+.020			
12	+.095	+.173	+.078			
12'	+.088	+.148	+.060			
13	+.104	+.137	+.033			
13'	+.071	+.125	+.054			
14						
14'						
15						
15'						
16						
16'						
17						
17'						
18						
18'	+.085	+.092	+.007			

Location of Points Measured



ΔL_i = Distance from a "zero point" or between 2 opposite points before thermal exposure.

ΔL_H = Distance from "zero point" or between 2 opposite points after thermal exposure.

ΔL_{H-i} = Dimensional change caused by thermal exposure.

Manually Determined Dimensional Changes Distr. No. 2 - Phase IIa "Thrust OK, S/N 0000017	Table VI Phase IIa

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MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

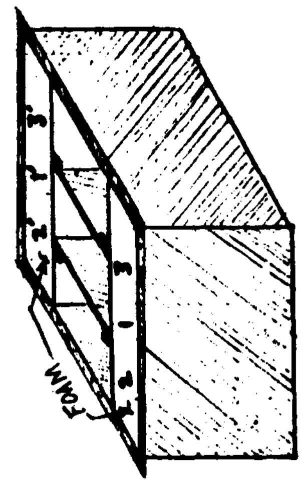
OVEN CYCLE

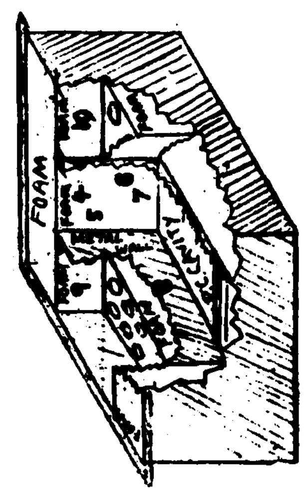
CYCLE: 180°F - 16 Hr.

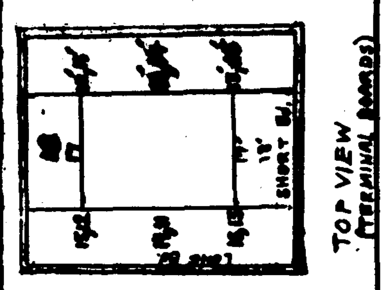
INCHES

Points Measured	ΔL_i	ΔL_H	ΔL_{H-i}	ΔL_i	ΔL_H	ΔL_{H-i}
1	-.015	-.007	+.008			
1'	-.044	-.047	-.003			
2	-.036	-.021	+.015			
2'	-.025	-.026	+.001			
3	-.015	-.014	-.001			
3'	-.044	-.037	+.007			
4	6.951	6.885	-.066			
5	7.069	6.984	-.085			
6	7.069	7.045	-.024			
7	7.101	7.032	-.079			
8	3.776	3.789	+.013			
9	7.084	7.102	+.018			
10	6.897	6.925	+.028			
11	+.188	+.104	-.084			
11'	+.181	+.191	+.010			
12	+.107	+.122	+.015			
12'	+.128	+.131	+.003			
13	+.153	+.168	+.015			
13'	+.149	+.158	+.009			
14	+.133	+.151	+.018			
14'	+.139	+.148	+.009			
15	+.104	+.116	+.012			
15'	+.116	+.119	+.003			
16	+.116	+.126	+.010			
16'	+.119	+.123	+.004			
17	+.194	+.103	-.091			
17'	+.081	+.080	-.001			
18	+.193	+.104	-.089			
18'	+.087	+.087	0			

Location of Points Measured







ΔL_i = Distance from a "zero point" or between 2 opposite points before thermal exposure.

ΔL_H = Distance from "zero point" or between 2 opposite points after thermal exposure.

ΔL_{H-i} = Dimensional change caused by thermal exposure.

Manually Determined Dimensional Changes Distr. No. 3 - Phase IIa "Timer", S/N 0000001	Table VII Phase IIa

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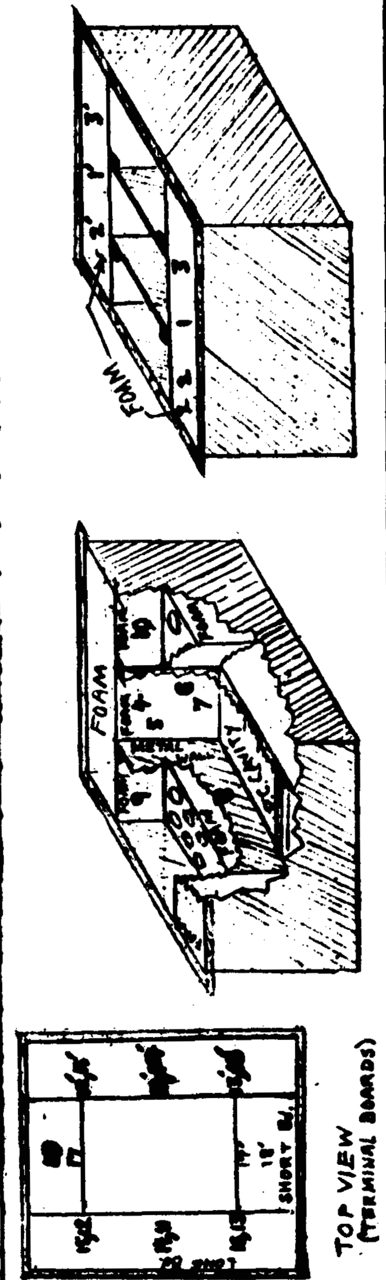
MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

OVEN CYCLE

CYCLE: 180°F - 16 HR.

Points Measured	INCHES ΔL_i	ΔL_H	ΔL_{H-i}	ΔL_i	ΔL_H	ΔL_{H-i}
1	0	-.043	-.043			
1'	-.013	-.058	-.045			
2	+.008	-.036	-.044			
2'	-.001	-.050	-.049			
3	+.004	-.043	-.047			
3'	-.025	-.052	-.027			
4	7.019	6.245	-.774			
5	7.124	6.792	-.332			
6	7.116	6.581	-.535			
7	7.066	6.691	-.375			
8	3.775	3.775	0			
9	6.905	6.4[illegible]	-.455			
10	6.990	6.4[illegible]5	-.585			
11	+.140	+.150	+.010			
11'	+.137	+.156	+.019			
12	+.130	+.127	-.003			
12'	+.158	+.165	+.007			
13	+.138	+.133	-.005			
13'	+.127	+.144	+.017			
14	+.131	+.135	+.004			
14'	+.124	+.127	+.003			
15	+.130	+.125	-.005			
15'	+.141	+.140	-.004			
16	+.124	+.115	-.009			
16'	+.123	+.127	+.004			
17	+.123	+.115	-.008			
17'	+.152	+.155	+.003			
18	+.125	+.122	-.003			
18'	+.126	+.127	+.001			

Location of Points Measured



ΔL_i = Distance from a "zero point" or between 2 opposite points before thermal exposure

ΔL_H = Distance from "zero point" or between 2 opposite points after thermal exposure

ΔL_{H-i} = Dimensional change caused by thermal exposure

Manually Determined Dimensional Changes
Distr. No. 4- Phase IIa
"Seq. & Control, S/N 0000003

Table [illegible]
Phase II

72

REV. SYM. ______

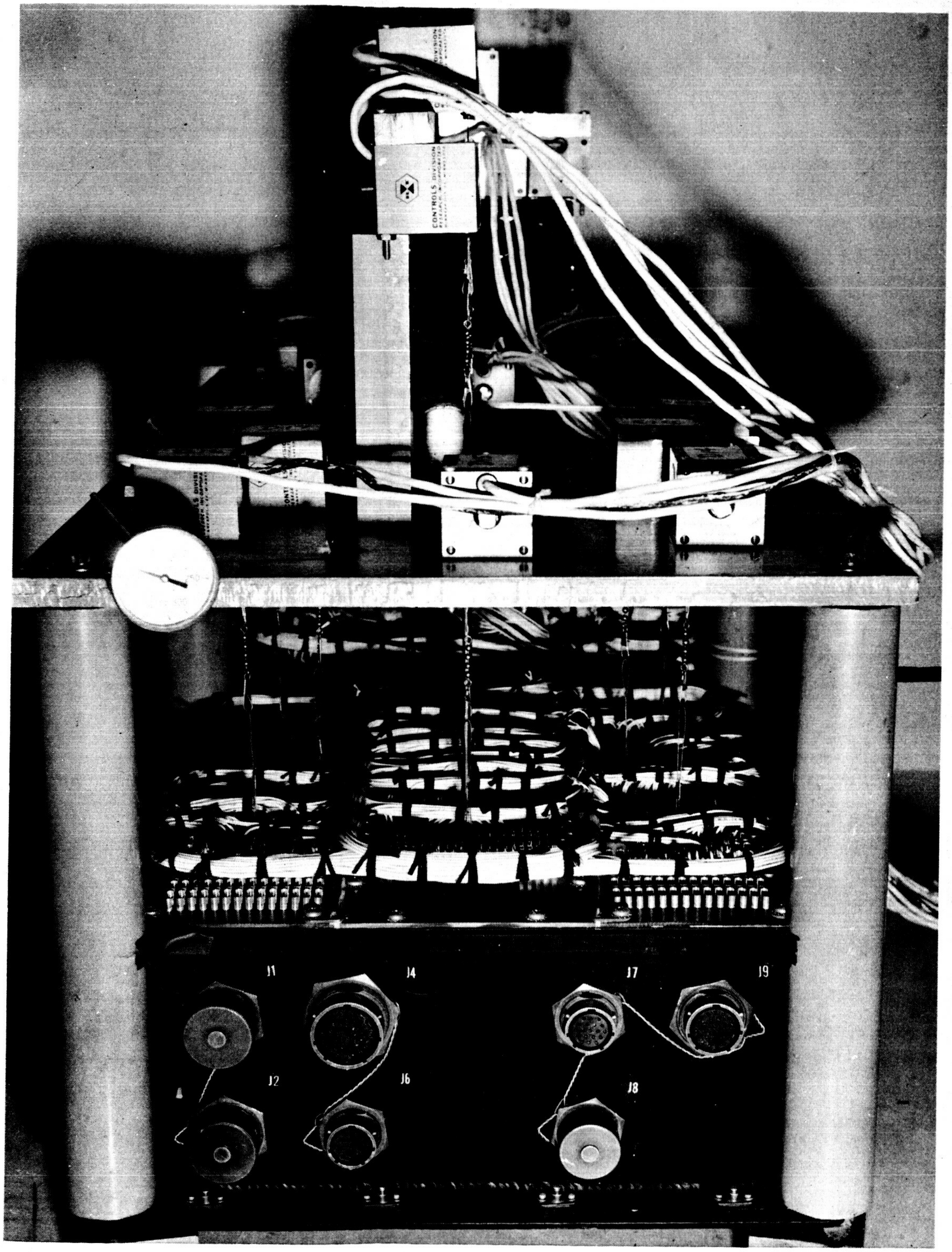


FIGURE Ia , PHASE IIa

Test Fixture For Determining Foam Expansion
With Electrical Deflection Transducers (Typical Setup)

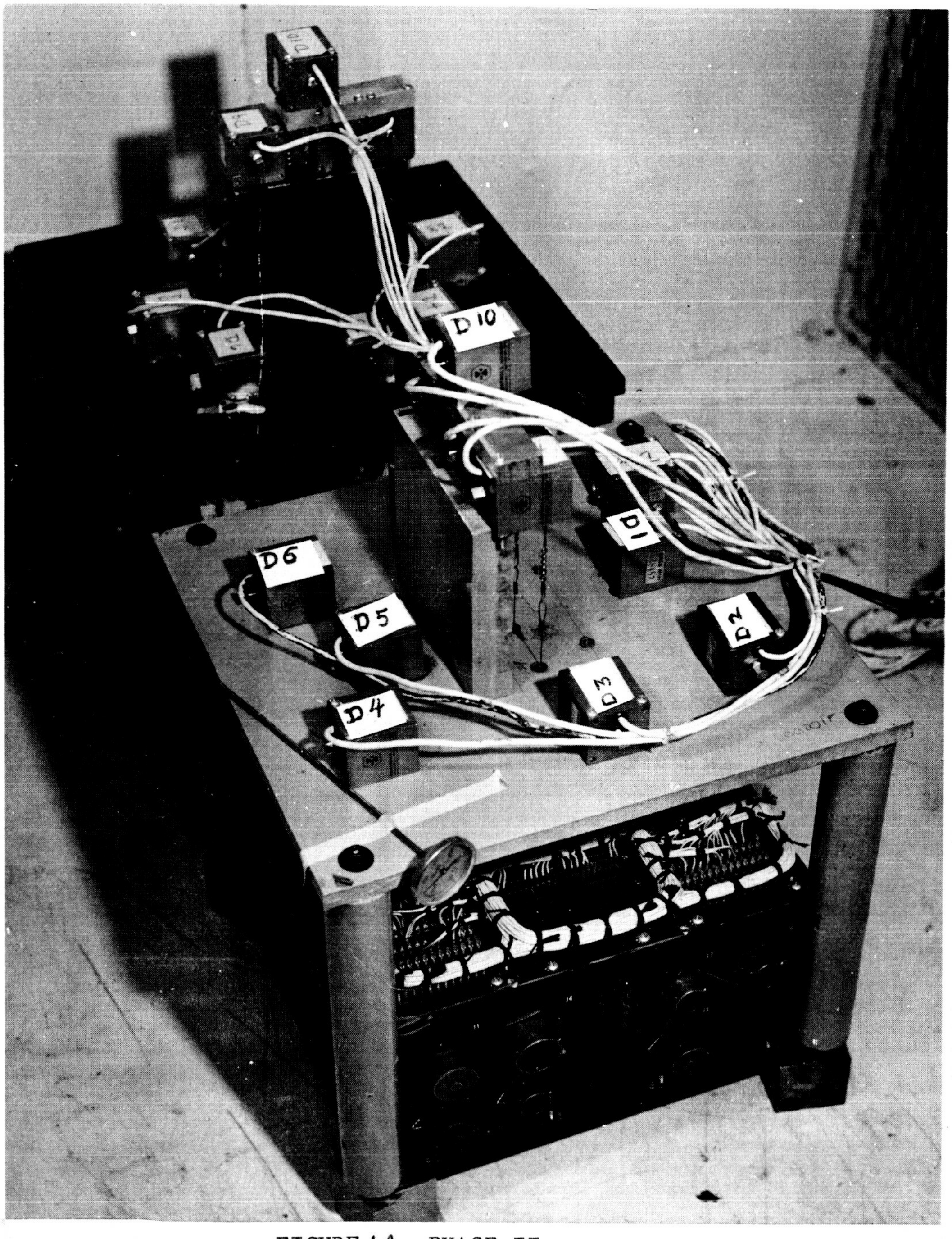


FIGURE 16, PHASE IIa

Test Fixture For Determining Foam Expansion
With Electrical Deflection Transducers (Typical Setup)

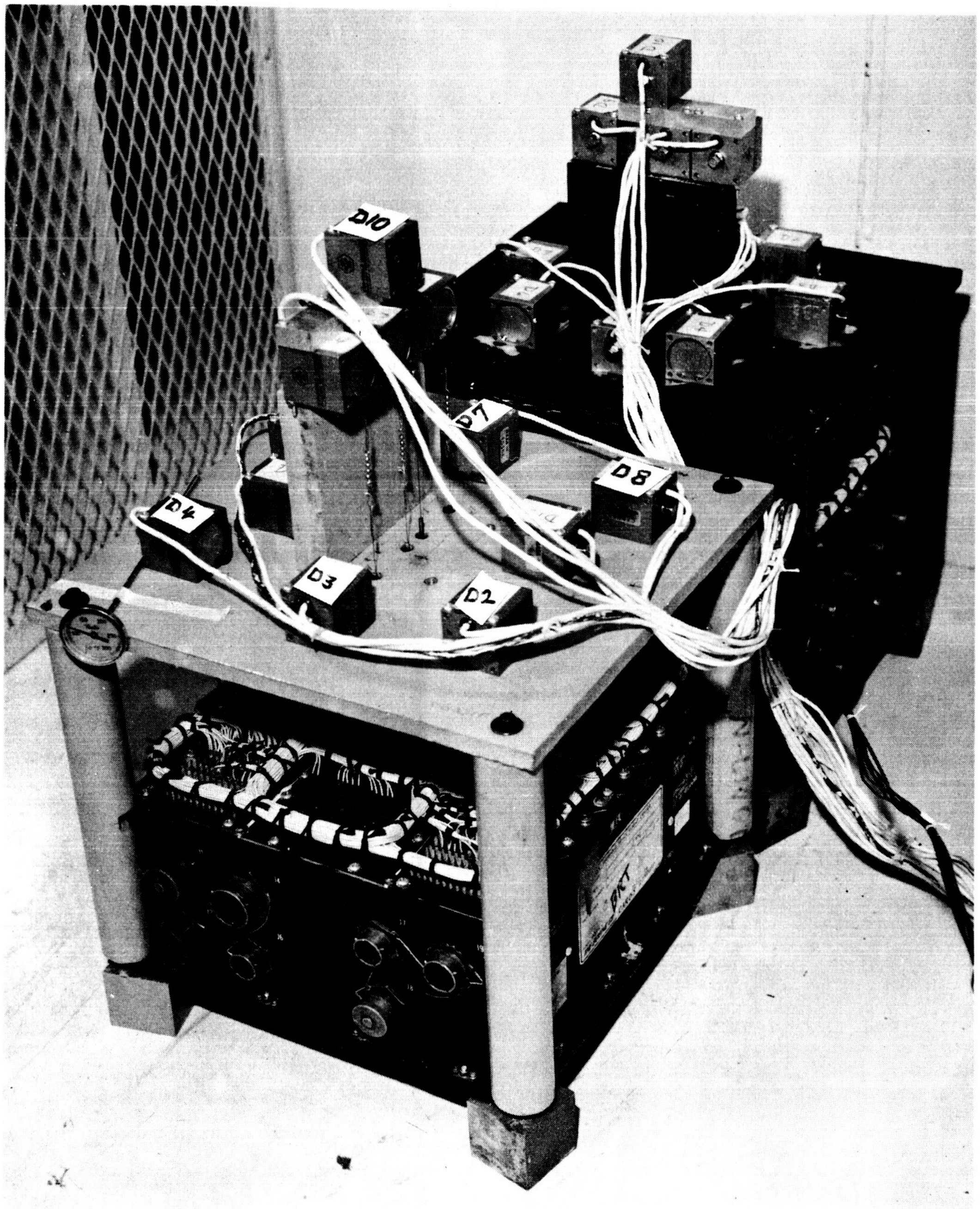


FIGURE 1c, PHASE IIa

Test Fixture For Determining Foam Expansion With Electrical Deflection Transducers (Typical Setup)

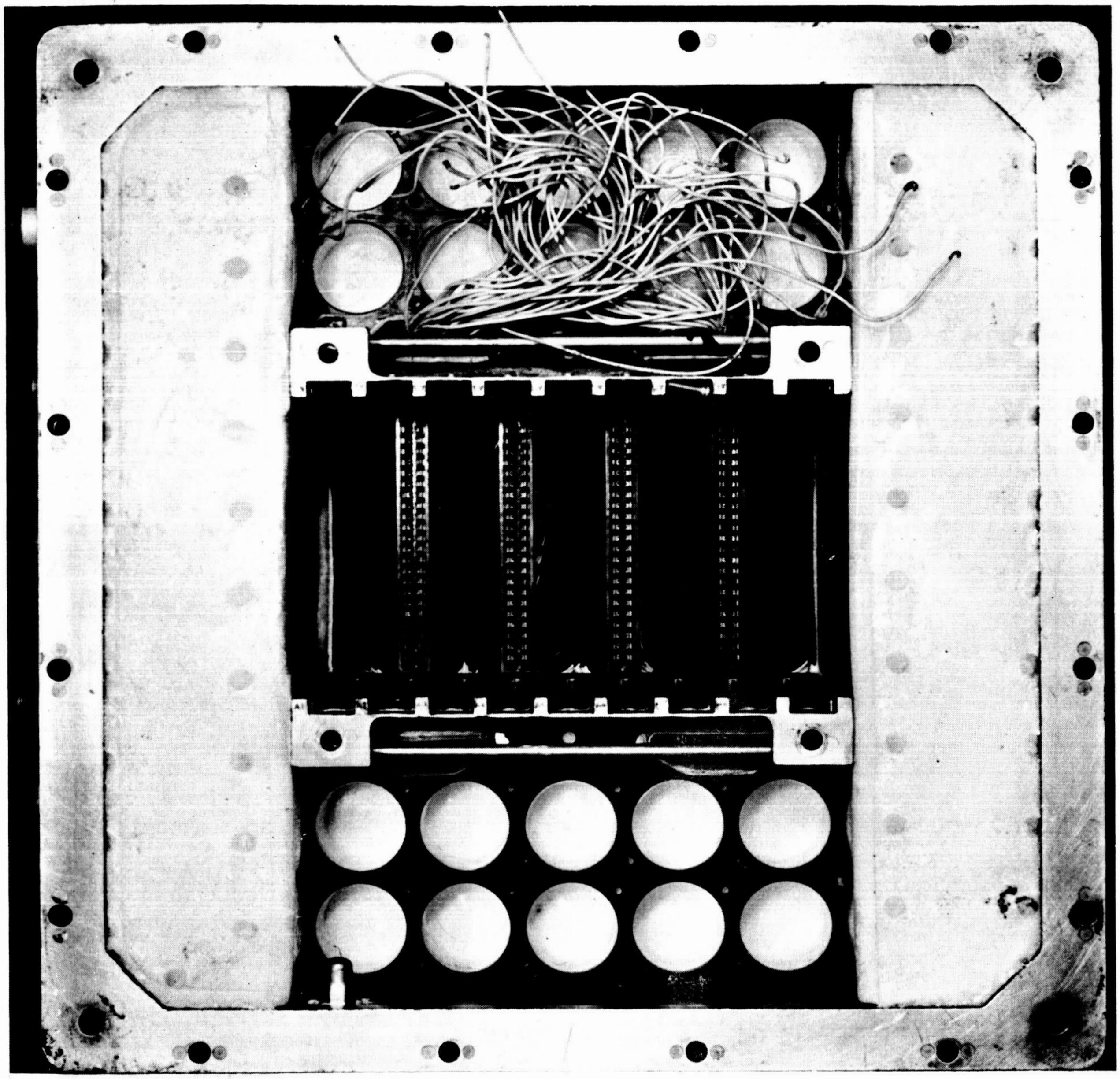


FIGURE 2a, PHASE IIa

Distributor No. 1: Before Oven Cycle

Identity: "Sequence & Control", 60B62028-7A, S/N 0000011, Mfg. 9/21/66

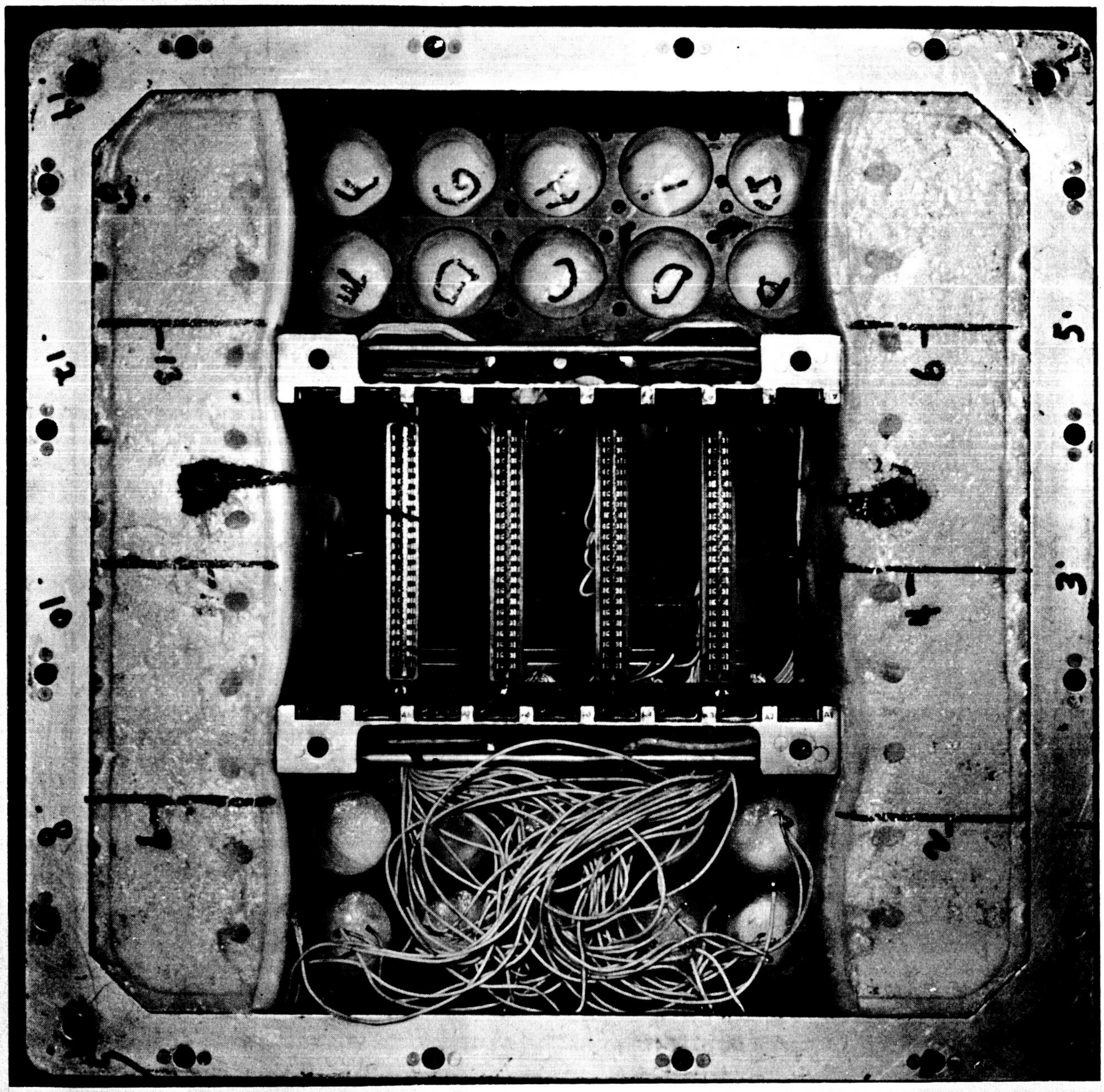


FIGURE 2b, PHASE IIa

Distributor No. 1: After Oven Cycle (180 ± 5°F - 22.5 Hr.)

Identity: "Sequence & Control", 60B62028-7A, S/N 0000011, Mfg. 9/21/66

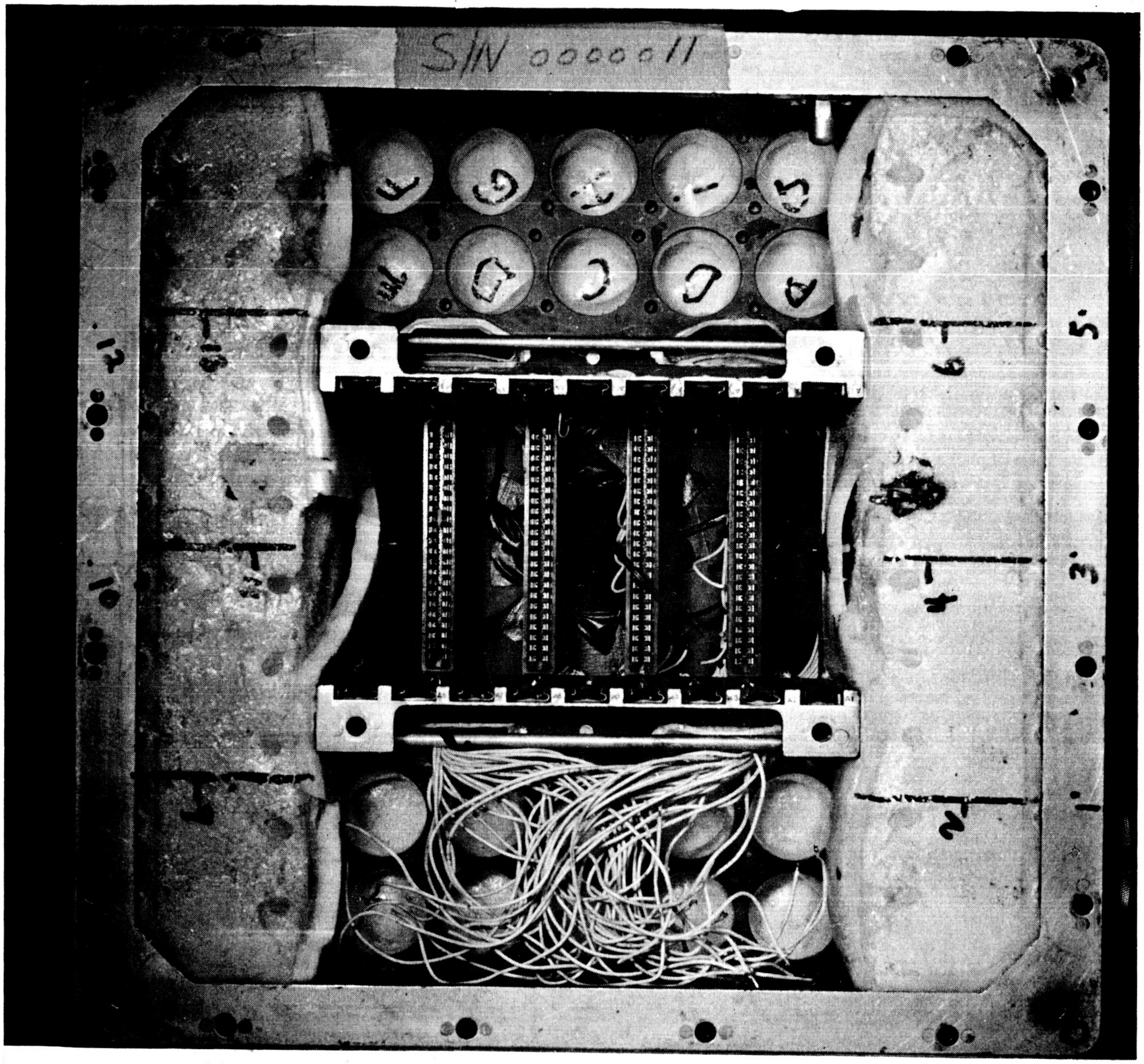


FIGURE 2c , PHASE IIa

Distributor No. 1: After Oven Cycle (180 ± 5^{o}F - 22.5 Hr.)

Preformed dam cut to show gas pocket

Identity: "Sequence & Control", 60B62028, S/N 0000011, Mfg. 9/21/66

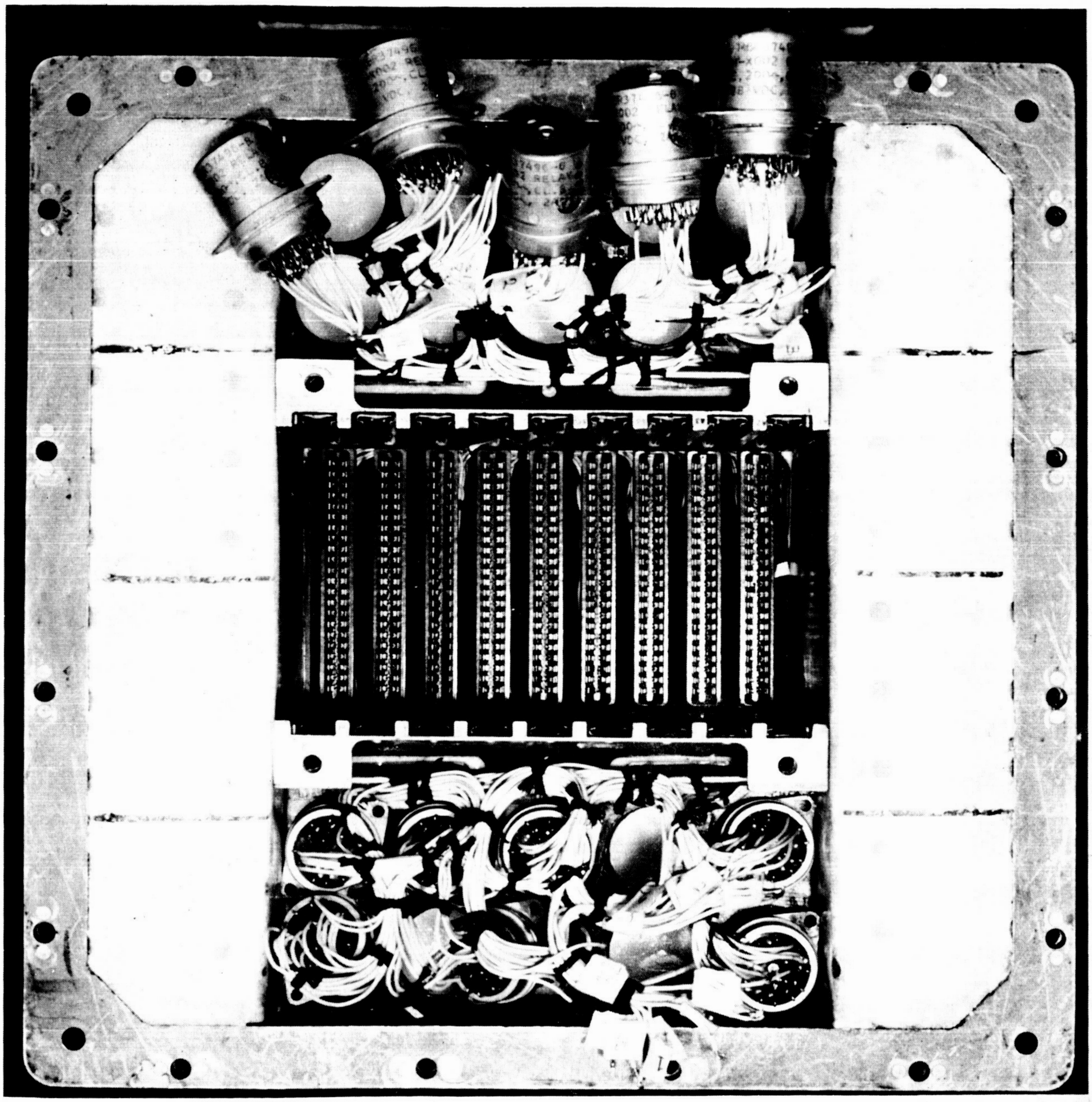


FIGURE 3a, PHASE IIa

Distributor No. 2: Before Oven Cycle

Identity: "Thrust OK", 60B62295-5A, S/N 0000017, Mfg. 6/6/66

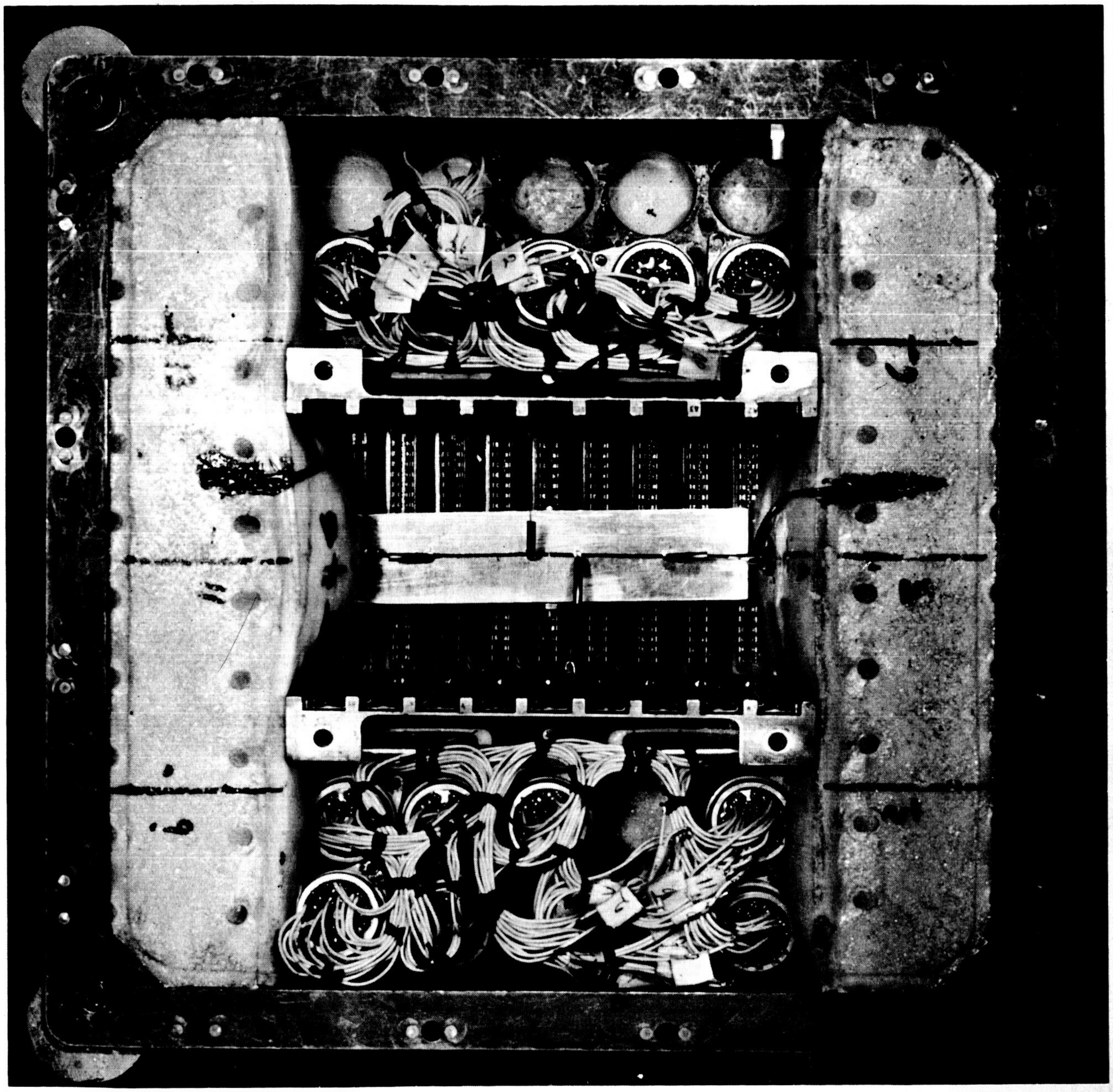


FIGURE 3b, PHASE IIa

Distributor No. 2" After Oven Cycle (180 $\pm$ 5^{o}F - 22.5 Hr.)

Identity: "Thrust OK", 60B62295-5A, S/N 0000017, Mfg. 6/6/66

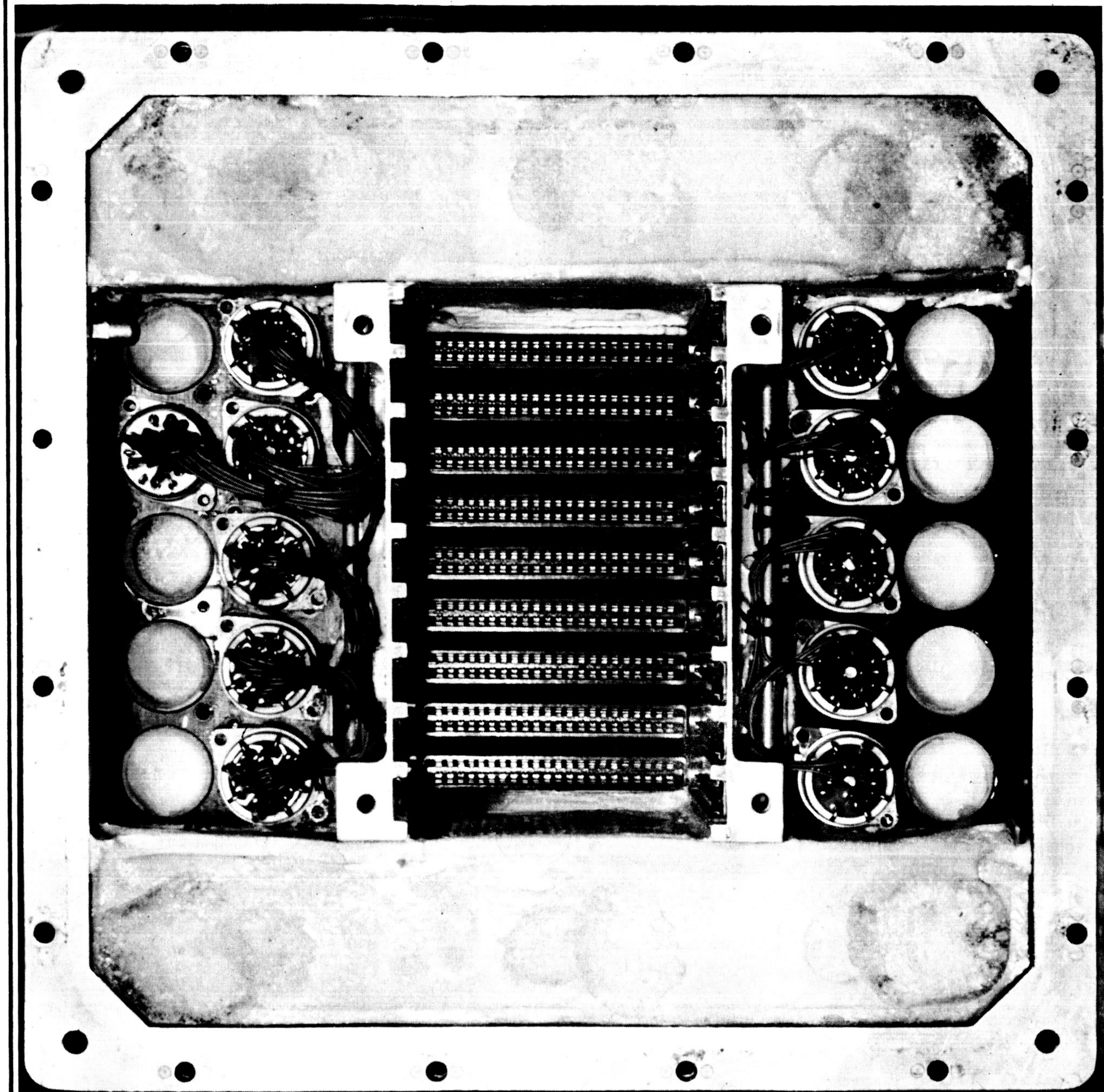


FIGURE 4a, PHASE IIa

Distributor No. 3: Before Oven Cycle

Identity: "Timer", 60B62030-1, S/N 0000001, Mfg. 8/4/65

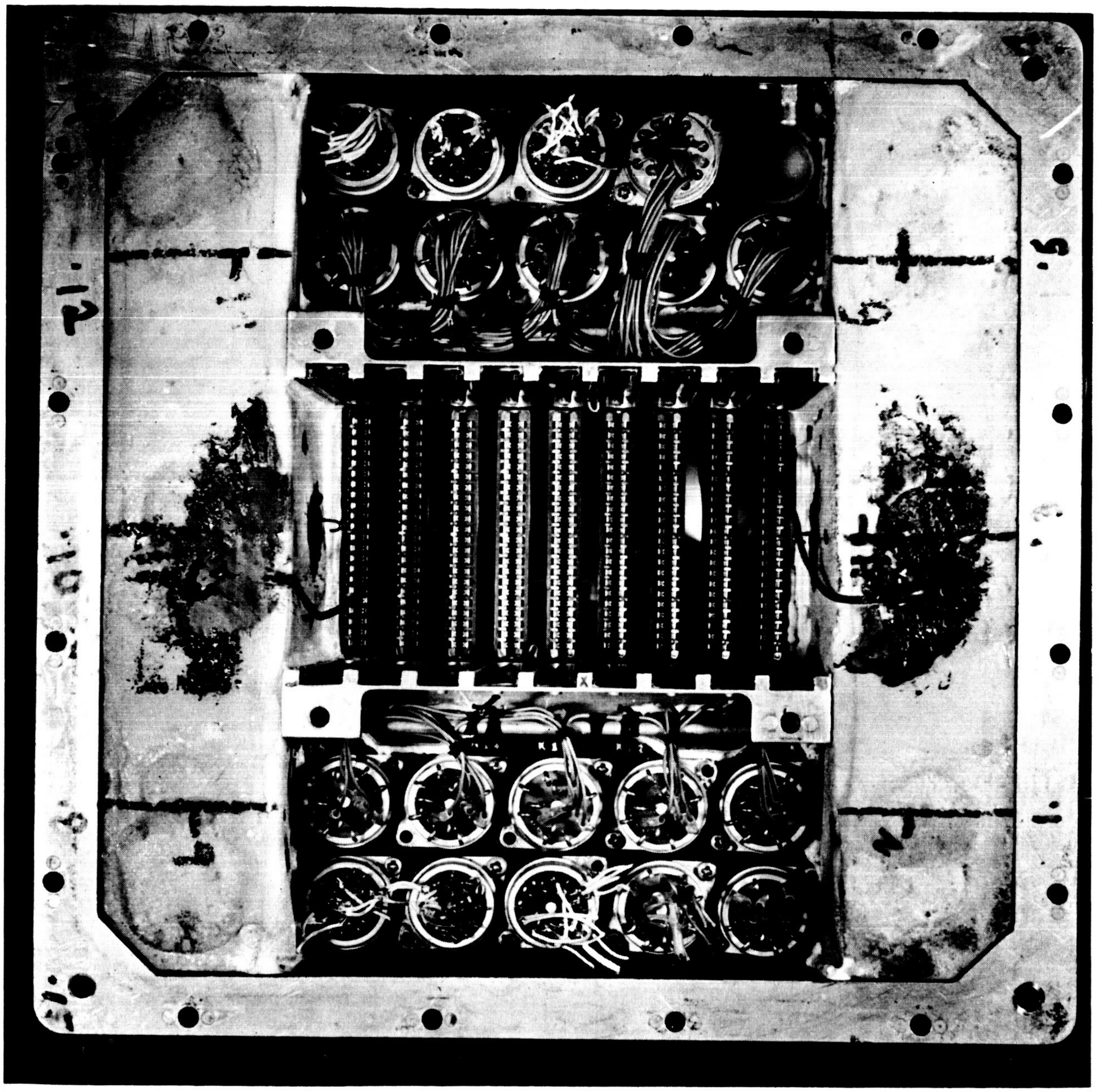


FIGURE 4b, PHASE IIa

Distributor No. 3: After Oven Cycle (180 $\pm$ 5°F - 16 Hr.)

Identity: "Timer", 60B62030-1, Mfg. 8/4/65, S/N 0000001

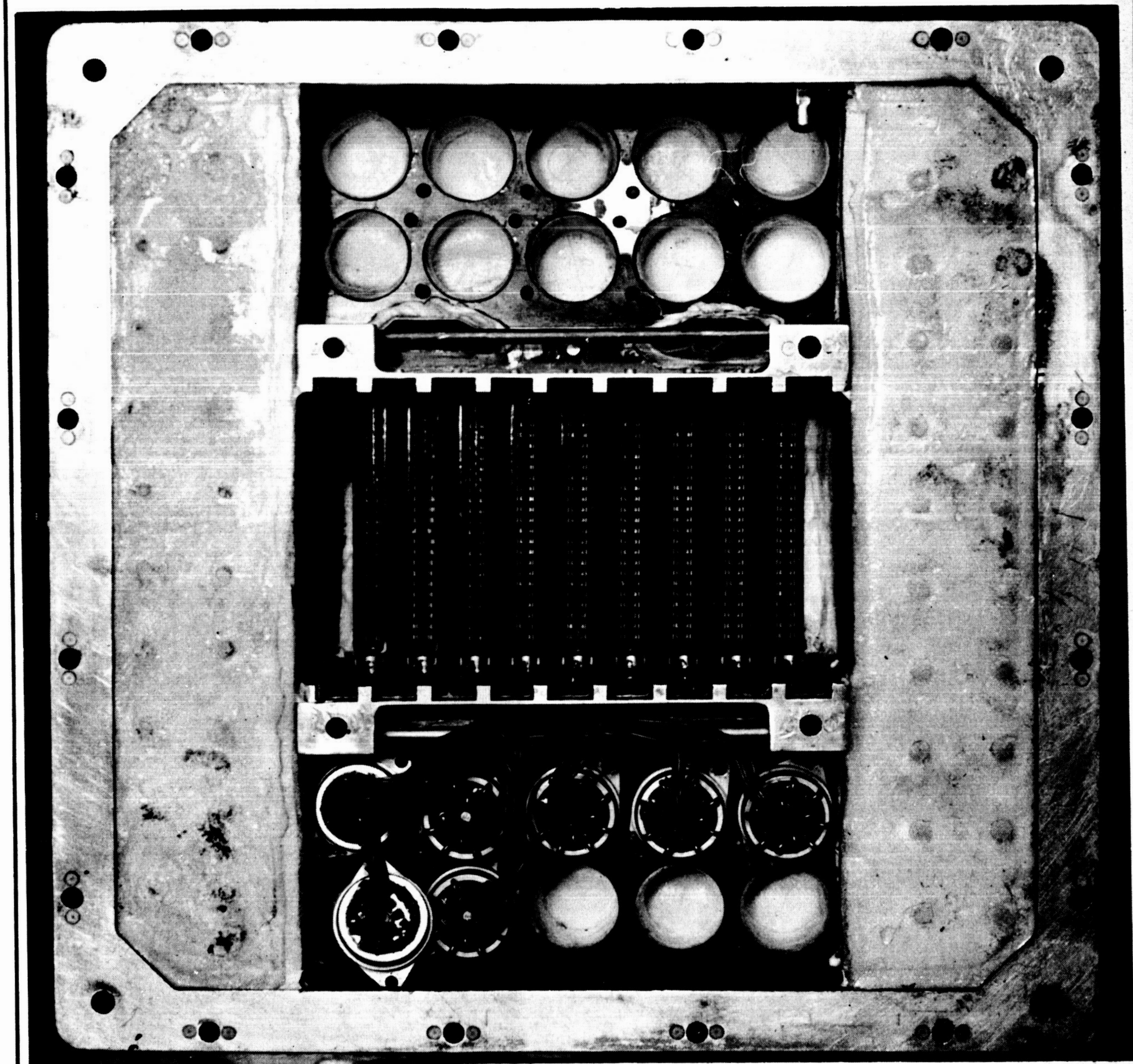


FIGURE 5a, PHASE IIa

Distributor No. 4: Before Oven Cycle

Identity: "Sequence & Control", 60B62028-1, S/N 0000003, Mfg. 8/6/65

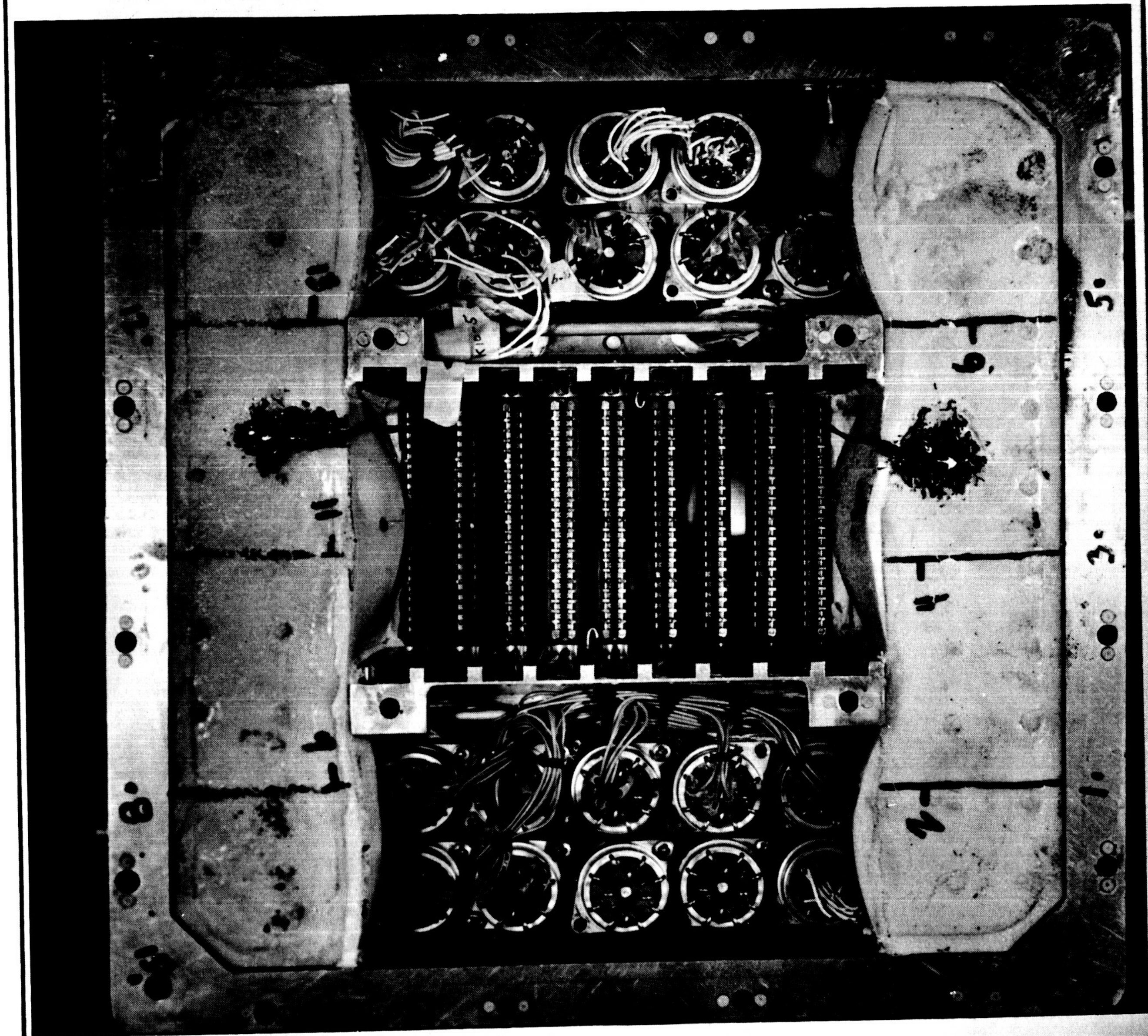


FIGURE 56, PHASE IIa

Distributor No. 4: After Oven Cycle (180 ± 5^oF - 16 Hr.)

Identity: "Sequence & Control, 60B62028-1, S/N 0000003, Mfg. 8/6/65

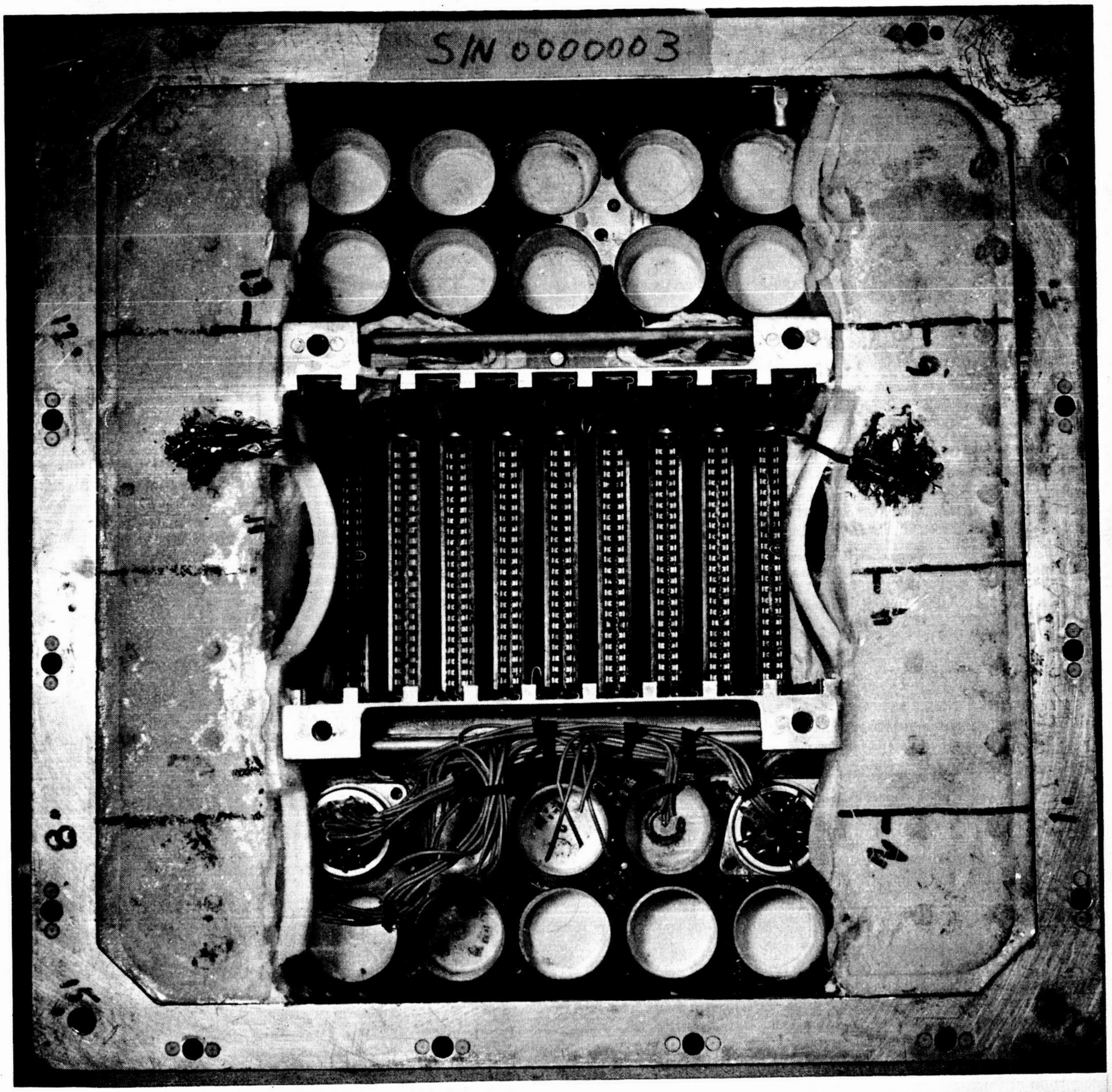


FIGURE 5c, PHASE IIa

Distributor No. 4: After Oven Cycle (180 ± 5°F - 16 Hr.)

Preformed dam cut to show gas pockets

Identity: "Sequence & Control", 60B62028-1, S/N 0000003, Mfg. 8/6/65

5.4 PHASE IIb

5.4.1 Objective

To determine the physical and electrical effects of foam expansion on printed circuit (p.c.) cards, p.c. card components and p.c. card connectors.

5.4.2 Identity of Distributors Tested

No. 1 "Thrust OK", 60B62295-5, S/N 0000019, Mfg. 6/27/67

History: Previously subjected to BRT but not exposed to elevated temperature that effected foam expansion. One of the foam walls of the p.c. card cavity had been trimmed back to clear the relay components on the p.c. card.

No. 2 "Propulsion", 60B62029-7, S/N 0000014, Mfg. 7/10/66

History: Previously subjected to BRT but not exposed to elevated temperatures that effected foam expansion. None of the foam walls had been trimmed.

5.4.3 Test Procedure

Printed circuit cards (relay and diode) were installed in the two end slots nearest the foam walls of the p.c. card cavity, in each distributor. (Total of 4 cards per distributor.) The arrangement is shown in Figures 1 and 2 which were taken after heating. (No before oven cycle pictures were obtained.)

Both covers (top and bottom) were replaced and the distributors were baked in an oven for 22 hours at 180 $\pm$ 5°F. (Note: The oven was cold to begin with and time at temperature, although not determined exactly, was approximately 19 hours. Results from Phase IIa showed that foam expansion stabilized after 12 hours. The oven used, as determined in other studies, takes approximately 1½ hours to heat from ambient to 180° $\pm$ 5°F.)

5.4.3 (Continued)

Static functional tests were run on the installed p.c. cards, in both distributors, before and after heating. Distributor No. 2 only, was functionally tested after heating, while being vibrated to qualification test levels, to detect any malfunction or relay chatter not indicated by the static functional test.

5.4.4 <u>Test Results</u>

5.4.4.1 Distributor No. 1 (Figure 1)

The foam wall that had been trimmed did not expand into the cards. The untrimmed wall expanded in to the relay mounting screws but did not bow the card. Static functional tests showed no malfunctions.

5.4.4.2 Distributor No. 2 (Figure 2)

The foam walls of the p.c. card cavity, neither of which had been trimmed, expanded into the adjacent p.c. cards, bowing the cards slightly. Because of this both static and vibrational functional tests were conducted - neither revealed any malfunctions or relay chatter.

Examination of Figure 2 shows that the foam walls at the ends of the relay cavities expanded further than did the corresponding p.c. card cavity walls. In Phase II a these walls expanded just as far or further than the relay cavity walls. This indicates that the p.c. cards, p.c. card components, slots and connectors are strong enough to prevent the foam from reaching its maximum expansion. Also, it was observed that the foam will tend to form around the card components @ 180^{o} F.

5.4.5 <u>Conclusions</u>

The tests showed that post foam expansion, when forced at 180^{o}F, will not impair the function of the p.c. cards. Although some bowing resulted, the cards, card connectors, etc. were strong enough to prevent "damaging" expansion. Even under vibration no malfunctions or relay chatter was detected.

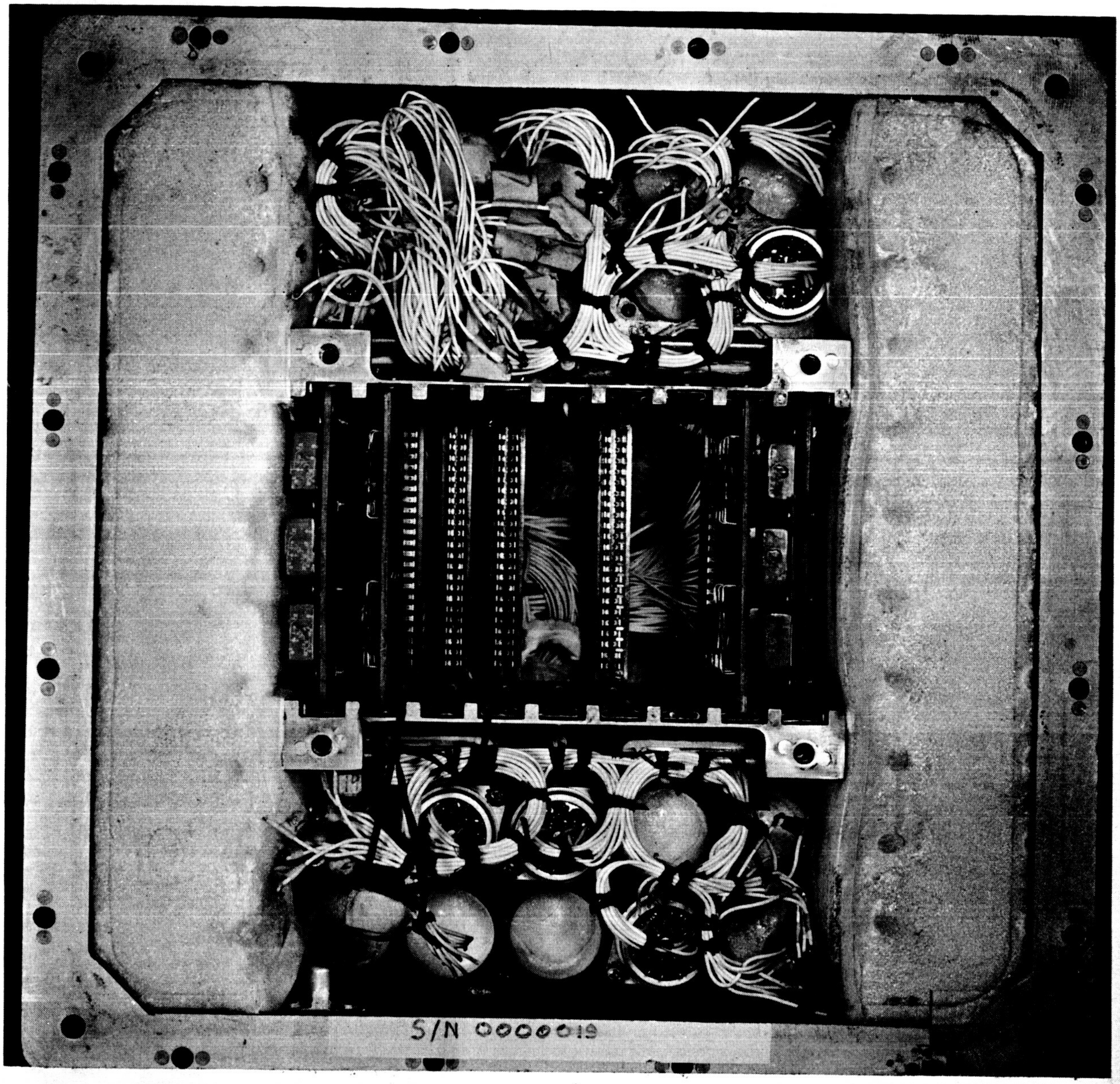


FIGURE 1 , PHASE IIb

Distributor No. 1: After Oven Cycle (180 $\pm$ 5°F - 22 Hr.)

Identity: "Thrust OK:, 60B62295-5, S/N 0000019, Mfg. 6/27/67.

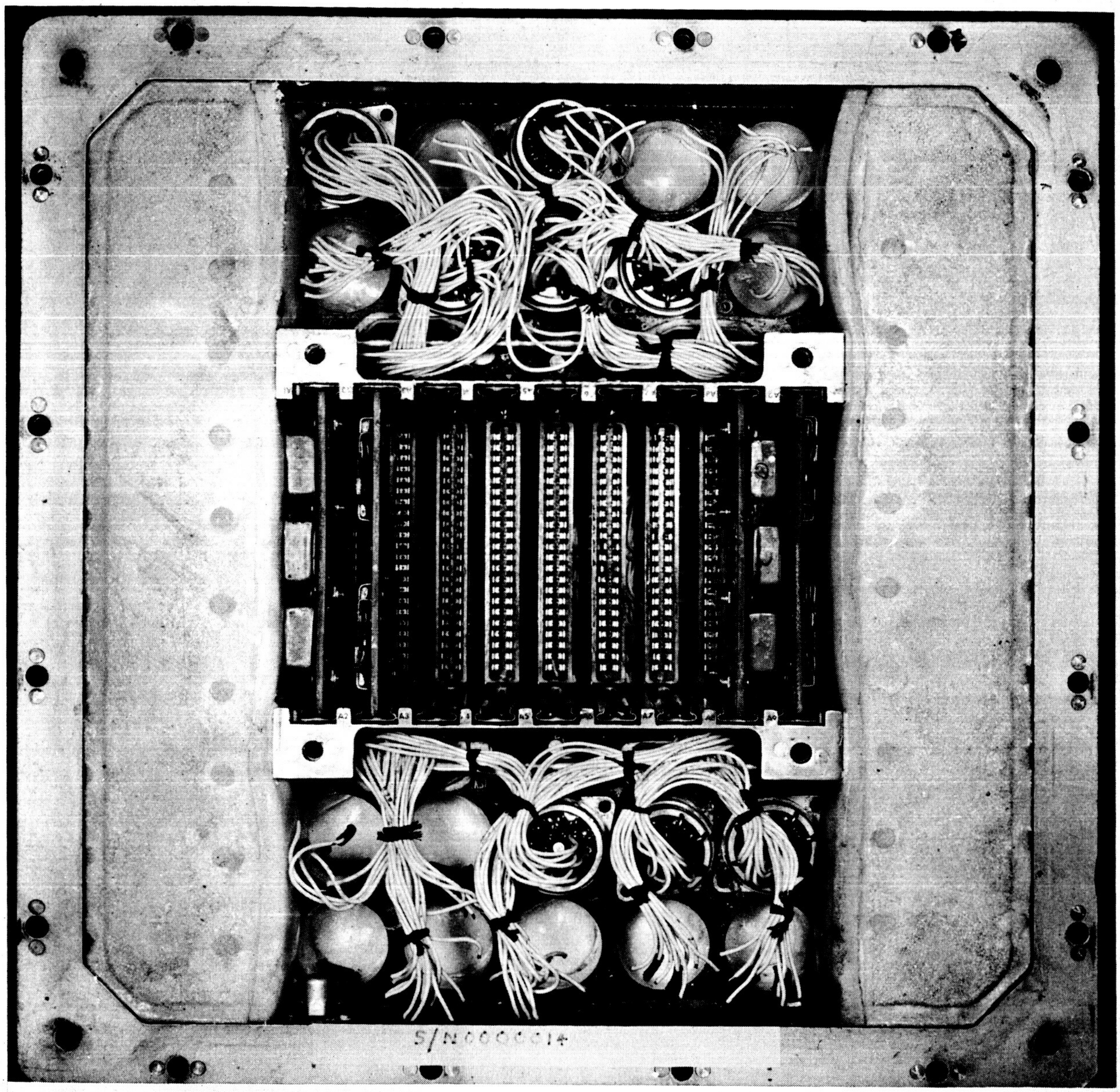


FIGURE 2 , PHASE IIb

Distributor No. 2: After Oven Cycle (180 $\pm$ 5°F - 22 Hr.)

Identity: "Propulsion", 60B62029-7, S/N 0000014, Mfg. 7/10/66.

5.5 PHASE IIIa

5.5.1 Objective

To evaluate an "oven fix" procedure to force potential post foam expansion, under controlled conditions, in a direction that will cause no damage and will be easy to remove, thereby preventing expansion after installation into the vehicle.

5.5.2 Identify of Distributor Tested

"Measuring Distributor", 60B62032-5A, S/N 0000007, Mfg. 6/8/66.

History: Rejected off the 503 (not because of foam expansion) and designated as "scrap". No previous elevated temperature exposure which effected foam expansion. All foam surfaces were intact. Figure No. 1 shows this distributor before heating.

5.5.3 Test Procedure

5.5.3.1 195° Oven Cycle

a. The vertical foam walls of the p.c. card cavity and of the relay cavities were reinforced by inserting metal "I" type supports to prevent lateral movement. The unsupported inside edge of the long terminal boards were reinforced with five metal clips spaced evenly along each board. These were secured with p.c. card connector mounting screws. The relay holes were left open. The top cover was replaced to protect the terminal board wiring. The bottom cover was left off to allow the foam to expand. The distributor was subjected to a nominal 24 hour, $195 \pm 5^{\circ}F$ oven cycle. (The oven was cold, initially, and took approximately one hour to reach temperature.)

b. Dimensional changes caused by the 195° thermal exposure were determined, manually, as described in Phase IIa.

c. Effects on continuity were determined with a Brooks analyzer.

5.5.3.2 180° Oven Cycle

After the necessary measurements were taken, following the 195° cycle, the excess (expanded) foam was removed from the bottom surface and from the relay holes. All supports were removed and the distributor was reassembled including relays, to simulate a typical flight configuration. It was then subjected to a nominal 24 hour $180^{\circ} \pm 5^{\circ}F$ oven cycle for 24 hours to show what good, with respect to preventing post expansion, the 195° cycle did. During this cycle, in addition to manual dimensional measurements, dimensional changes were also monitored with electrical deflection transducers as described in Phase IIa. Continuity was rechecked with a Brooks analyzer.

5.5.4 <u>Test Results</u>

5.5.4.1 Presentation of Data

Dimensional changes as determined manually are shown in Table I. Changes monitored with EDI are presented in Table II. Figure 1 shows the distributor before any heat exposure. Figure 2 shows the distributor after the 180^{o}F cycle. No pictures were obtained after the 195^{o} cycle.

5.5.4.2 Effects of Thermal Cycles on Continuity

Electrical tests run before and after each oven cycle showed no electrical discontinuity caused by the thermal cycles.

5.5.4.3 Dimensional Changes - 195^{o} Cycle

a. The foam expanded approximately .5" past the bottom flange. The distance between opposite walls of the p.c. card cavity and of the relay cavities showed very little change as shown in Table I. Two of the points (no's 4 & 10) measured showed a slight increase in distance while the others showed a slight decrease. This was probably caused by uneven surface contact between the faying surfaces of the foam and supports.

b. The top edge of the reinforcing supports was about ¼" short of the top of the foam walls and in this unsupported area more expansion was apparent. Therefore it is recommended that any supporting surfaces contact as much of the foam surface as practical.

c. The distance between the metal walls of the p.c. card cavity showed no change.

d. The foam expanded considerably into the empty relay holes. This was removed without any difficulty. However, it was later observed on another distributor, that wires may be embedded just beneath the foam surface. Therefore, it is recommended that relays or mandrels be installed in holes were expansion is undesirable.to prevent expansion in these areas, thus eliminating the risk of trimming.

e. The terminal boards showed no signifiacnt deflection.

5.5.4.4 Dimensional Changes - 180^{o} Cycle (Fig. 2)

a. The foam masses perpendicular to the p.c. card cavity showed a maximum linear expansion (toward the bottom of the distributor) of .007", as determined by manual measurements. Although the bottom cover was on during this cycle, expansion in this direction

5.5.4.4 (Continued)

was possible because of a small space, between the horizontal foam surface and the cover, caused by a slight concave type shrinkage that took place after removing the excess foam.

If this shrinkage is undersirable it can be minimized by allowing it to cool then to stress relieve (by removing supports) for several hours before removing the excess foam.

b. The distance between opposite foam walls of the p.c. card cavity decreased a maximum of .152", as determined manually (Table I). Deflections determined with EDI (Table II) showed that one wall deflected .07" and the other .04".

c. EDI measurements were not conducted on the foam walls of the relay cavities but manual measurements showed a .215" maximum decrease in the distance between opposite walls of one of the cavities. (The other decreased .113"). Although this is more lateral expansion than expected the foam did not expand against the relays nor did it contact the p.c. cards, inserted after the cycle.

In view of the lateral expansion results obtained it is recommended that the hard surfaced preformed dams be completely removed from the relay cavity areas and be partially removed or trimmed back to drawing dimensions in the p.c. card cavity area. Complete removal of the dams in the p.c. card cavity area might be "risky" because of wires that lay adjacent to the back side of the dams in some of the distributors. This was found to be the case in the distributor used in Phase IIIc of this study.

d. As in the preceeding 195^{o} cycle no significant deflections took place on the terminal board side or in the metal walls of the p.c. card cavity. Also the 180^{o} cycle caused no apparent adverse effects on the relay holes.

5.5.5 Conclusions and Recommendations

a. Results show that potential post foam expansion in already fabricated distributors can be forced and removed, under controlled conditions, without resulting in any functional damage to the distributors. Also that subsequent thermal exposure at 180^{o}F will not cause excessive additional expansion.

b. To completely eliminate the possibility of foam expansion into the p.c. cards or relays the following rework procedure is recommended:

Rework Procedure For Already Fabricated Distributors

1. Remove printed circuit cards.

5.5.5 (Continued)

2. Reinforce the terminal boards to prevent movement by the expanding foam.

3. Install relays or mandrels to prevent closing of the relay holes by the expanding.foam. (This step assumes that the relays can safely withstand the 195°F/24 hr. oven cycle).

4. Remove the hardsurfaced preformed foam partition from the ends of the relay cavities. (This surface is about .25" thick).

5. Remove approximately 1/8" off the horizontal (bottom) surfaces of the foam masses located at each end of the p.c. card cavity.

6. Reinforce the vertical foam walls of the p.c. card cavity and of the relay cavities to prevent lateral expansion. The faying surfaces of reinforcement tooling should cover as much of the foam surface as practical.

7. Leave the bottom open to allow the foam to expand out the bottom.

8. Heat in an oven for 24 hours @ 195 $\pm$ 5°F.

9. Remove from oven and allow to cool slowly to room temperature.

10. Remove lateral expansion restrainers and allow to set over night to relieve compressive stresses.

11. Remove excess foam from horizontal (bottom) surface.

12. Trim the vertical foam walls of the p.c. cavity to drawing dimensions.

    CAUTION: Trim carefully so as not to damage any wires. In some of the distributors the wiring may be contacting the back side of the preformed foam partition.

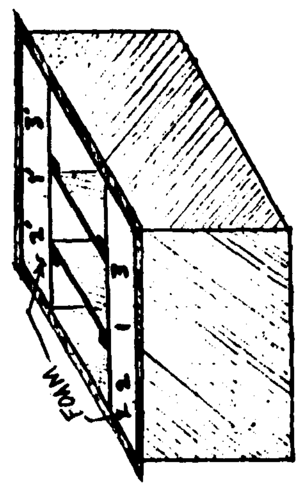
13. Remove all reinforcement tooling. Vacuum clean to remove all loose foam particles.

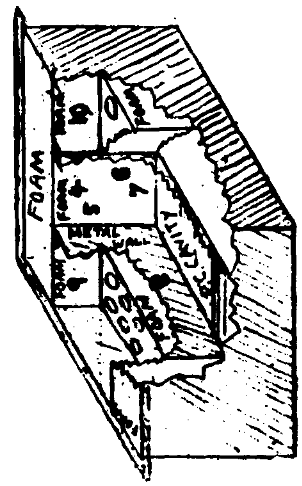
14. Replace electrical components and covers. Run functional tests.

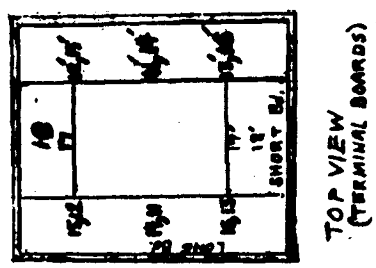
MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

CYCLE:	OVEN 195°F - 24 HR.			OVEN 180°F - 24 HR.		
Points Measured	L_i (INCHES)	L_H	L_{H-i}	L_i	L_H	L_{H-i}
1	+.019	+.390	+.371	-.038	-.095	-.057
1'	+.018	+.485	+.467	-.024	-.052	-.028
2	+.013	+.377	+.364	-.027	-.056	-.029
2'	+.025	+.427	+.402	-.056	-.049	+.007
3	+.024	+.456	+.432	-.029	-.047	-.018
3'	+ .018	+.459	+.441	-.043	-.056	-.013
4	6.951	6.965	+.014	6.963	6.811	-.152
5	6.975	6.971	-.004	6.975	6.848	-.126
6	6.990	6.965	-.025	6.959	6.850	-.109
7	6.964	6.935	-.029	6.932	6.855	-.077
8	3.775	3.775	0	3.775	3.770	-.005
9	7.009	7.000	-.009	6.935	6.822	-.113
10	7.000	7.012	+.012	7.016	6.801	-.215
11	+.127	+.107	-.020	+.117	+.124	+.007
11'	+.123	+.129	+.006	+.137	+.138	+.001
12	Could	Not Det	ermine	+.122	+.113	-.009
12'	+.121	+.114	-.007	+.125	+.128	+.003
13	+.134	+.114	-.020	+.132	+129	-.003
13'	+.124	+.118	-.006	+.135	+.140	+.005
14	+.121	+.117	-.004	+.128	+.119	-.009
14'	+.111	+.125	+.014	+.143	+.113	-.030
15	+.114	+.121	+.007	+.127	+.124	-.003
15'	+.118	+.122	+.004	+.136	+.113	-.023
16	+.123	+.120	-.003	+.141	+.129	-.012
16'	+.114	+.122	+.008	+.140	+.126	-.014
17	+.106	+.111	+.005	+.101	+.130	+.029
17'	+.093	+.095	+.002	+.095	+.098	+.003
18	+.105	+.105	0	+.103	+.113	+.010
18'	+.095	+.098	+.003	+.095	+.101	+.006

Location of Points Measured







L_i = Distance from a "zero point" or between 2 opposite points before thermal exposure

L_H = Distance from "zero point" or between 2 opposite points after thermal exposure

L_{H-i} = Dimensional change caused by thermal exposure

Manually Determined Dimensional Changes "Measuring Distr", S/N 0000007

TABLE X

PHASE IIIa

DISTRIBUTOR DEFLECTION AND TEMPERATURE DATA

DISTRIBUTOR NOMENCLATURE Measuring Distributor (503 Flight Distributor) DISTRIBUTOR SERIAL NUMBER 0000007 MFG. 6-8-66 DATE 3/17/67

TIME	DEFLECTION IN INCHES												TEMPERATURE °F			REMARKS
MIN/HRS	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	T.C. 1	T.C. 2	T.C. 3	
0	0	0	0	0	0	+.01	0	0	+.01	0	0	0	75	75	75	See Table I, Phase IIa
15	0	0	0	0	0	0	0	0	+.01	0	0	0	93	95	82	for location of points monitored.
30	0	0	0	0	0	0	0	0	+.01	0	0	0	109	112	100	
45	0	0	0	0	0	0	0	0	+.01	0	0	0	124	117	115	
60	0	0	0	0	0	0	0	0	+.01	-.01	-.01	0	137	139	128	
75	-0.01	0	0	0	0	0	0	0	0	-.01	-.01	0	150	152	143	
90	-0.01	-.01	-.01	-.01	0	0	-.01	-.01	+.01	-.01	-.01	0	161	163	153	
105	0	-.01	-.01	0	0	0	-.01	-.01	+.02	-.02	-.01	0	170	172	165	
120	0	-.01	-.01	0	0	0	-.01	-.01	+.03	-.01	-.02	+.02	173	173	170	
135	0	-.01	-.01	0	0	0	-.01	-.01	+.04	-.02	-.01	+.02	174	175	173	
150	0	0	-.01	0	0	0	-.01	-.01	+.05	-.01	-.01	+.02	175	176	175	
165	-0.01	-.01	-.01	0	0	-.01	-.01	0	+.06	-.02	-.01	+.03	175	176	175	
180	0	-.01	-.01	0	0	0	-.01	-.01	+.06	-.01	-.01	+.03	175	176	175	
195	0	-.01	-.01	0	0	0	-.01	-.01	+.06	-.02	-.01	+.03	175	176	175	
210	0	-.01	-.01	0	0	0	-.01	-.01	+.07	-.02	-.01	+.03	175	176	176	
225	0	0	-.01	0	0	0	-.01	-.01	+.06	-.02	-.02	+.03	175	176	176	
240	0	0	-.01	0	0	0	-.01	-.01	+.06	-.01	-.01	+.03	175	176	176	
8 HRS	-0.01	-.01	-.01	0	0	-.01	-.01	-.01	+.07	-.02	-.01	+.03	175	176	176	
12 HRS	0	0	-.02	0	0	-.01	-.02	-.01	+.06	-.03	-.02	+.02	176	177	176	
16 HRS	0	-.01	-.01	0	0	0	-.01	-.01	+.08	-.02	-.02	+.04	176	177	176	
20 HRS	-0.01	-.01	-.01	0	0	0	-.01	-.01	+.08	-.02	-.01	+.04	176	177	176	
23.5 HRS	0	-.01	-.01	-.01	0	0	-.01	-.01	+.07	-.02	-.02	+.04	173	173	173	
Full Scale Deflection	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.75	0.50	0.50	0.75				Accuracy: ±5% of full scale.

TIME OF MAX. DEFLECTION

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
								90 MIN			106 min

Determination of Dimensional Stability of Cured BMS 8-38, Type I, Gr. "FR" Foam "Measuring Distr", S/N 0000007, Phase IIIa, Table II

REV. SYM. ____

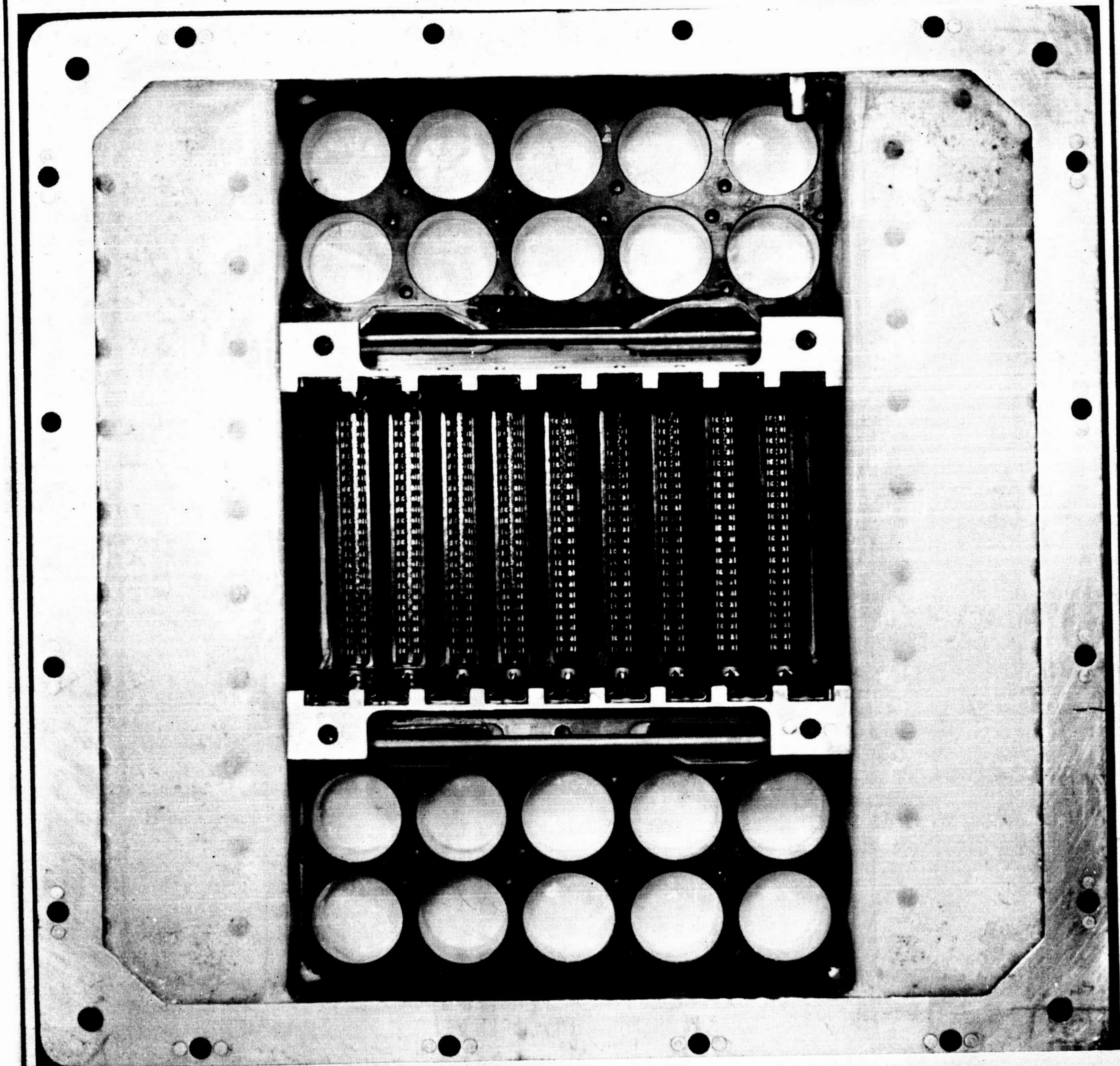


FIGURE 1, PHASE IIIa

Before Oven Cycle

Identity: "Measuring Distributor", 60B62032-5A, S/N 0000007, Mfg. 6/8/66

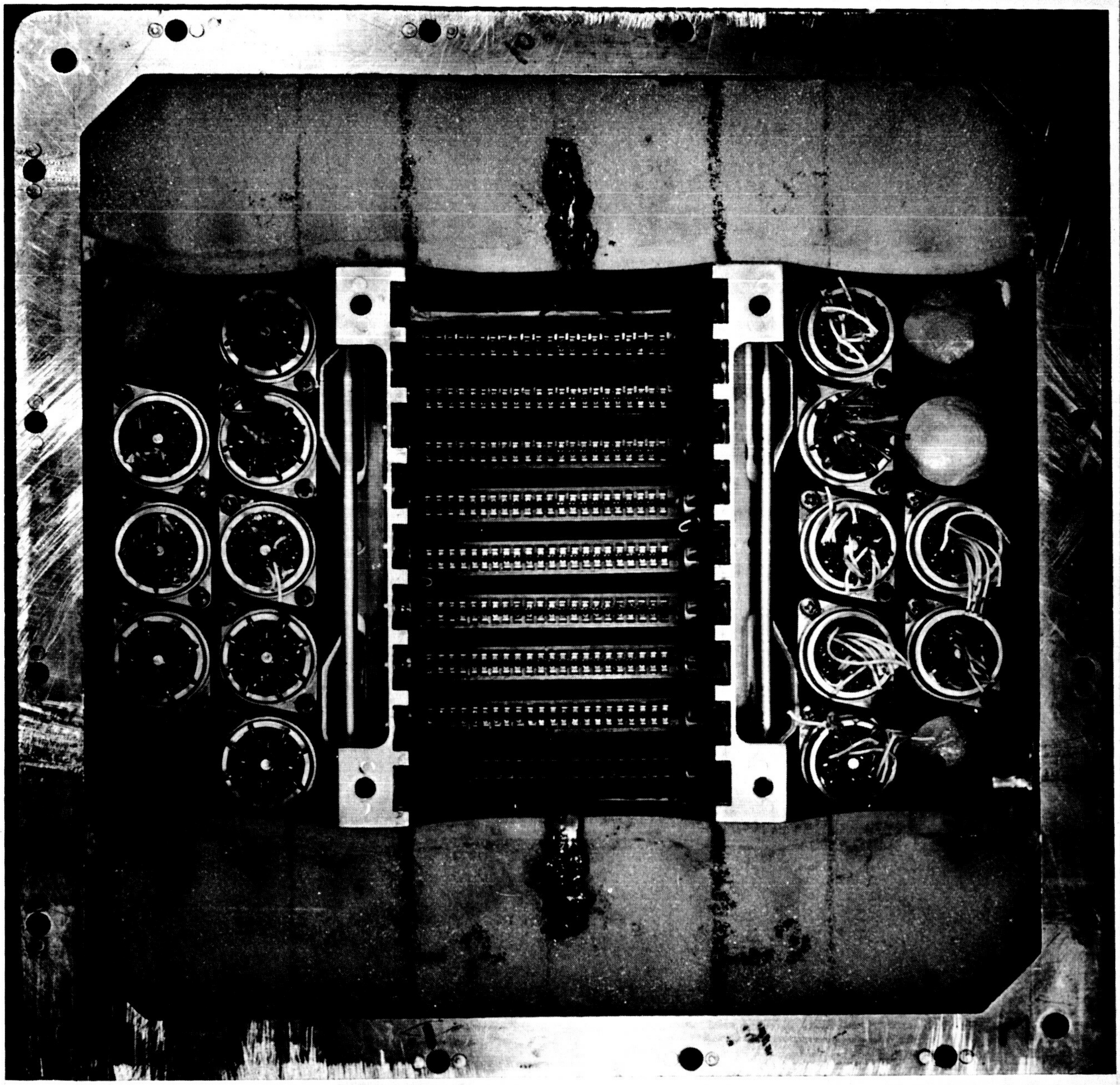


FIGURE 2, PHASE IIIa

After Oven Cycle ($180^{o} \pm 5^{o}F$ - 24 Hr.)

Identity: "Measuring Distr.", 60B62032-5A, S/N 0000007, Mfg. 6/8/66

5.6 PHASE IIIb

5.6.1 Objective

To evaluate an "autoclave fix" procedure by accelerating foam cure by the application of heat and restricting foam movement or expansion by external dry fluid pressure; thereby preventing post expansion after installation into the vehicle.

5.6.2 Identity of Distributors Tested

No. 1: "Timer", 60B62030-1, S/N 0000002, Mfg. 8/5/65

History: Previously subjected to BQT but not exposed to any elevated temperatures that effected foam expansion. One of the p.c. card cavity foam walls had been trimmed; the other surfaces were intact. Figure 1a shows this distributor before heating.

No. 2" Previously subjected to BRT. Exposed to 160°F for 16 hours prior to autoclave cycle.(1) One foam wall of the p.c. card cavity had been trimmed; the other walls were intact. Figure 2 shows this distributor before any thermal exposures.

5.6.3 Test Procedures

5.6.3.1 Test Conditions

a. Distributor No. 1 was subjected to a 170°F - 20 psig - 20 hr. autoclave cycle; then to a 24 hour 180° ± 5°F oven cycle to show what good the autoclave cycle did. (The desired autoclave temperature was 195°F but due to a malfunction we only achieved 170°).

b. Distributor No. 2 was subjected to a 195°F - 15 psig - 20 hr. autoclave cycle, followed by the 180° oven cycle, as above.

5.6.3.2 Measurements

a. The effects of each autoclave and each oven cycle on electrical continuity were determined with a Bendix Analyzer.

b. Dimensional changes caused by each cycle were measured, manually, as described in Phase IIa.

(1) It was desired to determine the affects of a 160°F oven cycle on foam expansion. Due to the lack of another distributor, No. 2 was used. Although not part of the planned "autoclave fix", the effects of the 160° cycle are discussed and results of dimensional changes are shown on page 1 of Table II. It should be realized that the subsequent "autoclave fix" results would probably have shown greater dimensional changes had the distributor not been subjected to the prior 160° cycle.

5.6.4 Test Results

5.6.4.1 Presentation of Data

Dimensional data for distributor No. 1 is presented in Table I, which consists of 2 pages. Table II (3 pages) shows data for distributor No. 2. Figures 1a, 1b, and 1c show distributor No. 1 before and after the autoclave cycle. No after "oven cycle" pictures were obtained. Figure 2 shows distributor No. 2 before the 160° oven cycle (See ① page 90.) No "after autoclave or 180° oven cycle" pictures were obtained.

5.6.4.2 Effects on Electrical Continuity

Tests conducted, on both distributors, before and after each autoclave cycle and after each oven cycle showed no evidence of open circuits caused by foam expansion.

5.6.4.3 Dimensional Changes - Distributor No. 1

a. Effect of autoclave cycle (170°F - 20 psig - 20 Hr)

This autoclave cycle caused a concave type depression of the vertical foam walls; being more pronounced on the untrimmed wall. This is shown in Figures 1b and 1c. Data points 4 thru 7 (page 1 of Table I) shows that the distance between the foam walls increased as much as 1.09". The distance between opposite walls of the relay cavities (points 9 & 10) increased .158" and .246". The horizontal bottom surfaces were depressed below the bottom flange a maximum of .280". The terminal boards showed no significant deflections. There were no apparent adverse effects on the "Union Switch Relay" holes. From these results it appears that 20 psig was too great a pressure at the time and temperature used. In view of this - distributor No. 2 was tested at 15 psig.

b. Effects of 180° Oven Cycle - Distributor No. 1

After the 180°F - 24 hour oven cycle the depressed foamed surfaces showed a considerable degree of recovery(expansion). Some points even expanded beyond the original dimensions. This is shown on page 2 of Table I. The maximum linear expansion beyond the original dimensions was .124". The maximum lateral expansion (into the p.c. cavity) was .038".

5.6.4.4 Dimensional Changes - Distributor No. 2

a. After 160° - 16 hr. oven cycle (see ①, page 90)

The distributor was placed in a 160°F oven, without the bottom cover. The foam expanded vertically .1" to .2". Lateral expansion decreased the distance between opposite vertical foam walls a maximum of .167" - this would have been greater if the bottom cover had been in place. A maximum deflection of .03" was measured on the terminal board side.

5.6.4.4 (Continued)

b. After autoclave cycle (195°F - 15 psig - 20 hr)

This autoclave cycle did not prevent linear expansion out the bottom or lateral expansion into the cavities, as shown by page 2, Table II. The linear expansion ranged from .03" to .07". The lateral expansion decreased the distance between opposite vertical foam walls a maximum of .135". The maximum terminal board deflection was .009".

c. After 180° oven cycle - Distributor No. 2

Table II, page 2, shows that expansion continued during the oven cycle. The maximum linear expansion was .012". Lateral expansion decreased the distance between opposite foam walls a maximum of .036". With respect to original dimensions (Before autoclave cycle), the maximum linear growth was .07" and the maximum distance decrease between foam walls was .162" - these data are shown on page 3 of Table II.

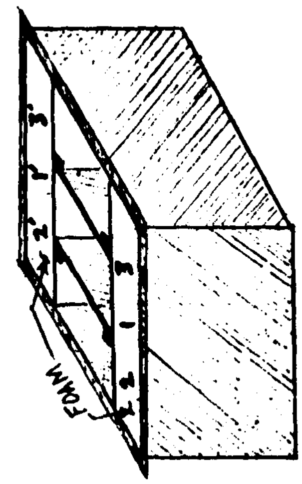
5.6.5 Conclusions

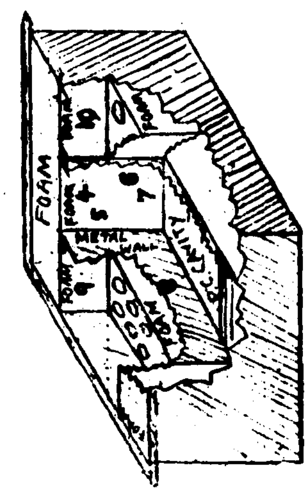
Due to a malfunctioning autoclave and a limited number of virgin specimens the results from this test phase are considered as indicative only and not conclusive. These indications are that the autoclave cycle will not satisfactorily prevent post foam expansion in already fabricated distributors.

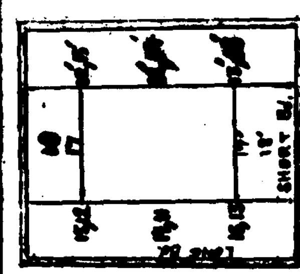
MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

CYCLE:	AUTOCLAVE 170°F - 20 PSI - 20 HR.			OVEN 180°F - 24 HR.		
Points Measured	INCHES ΔL_i	ΔL_H	$\Delta L_{H \pm i}$	ΔL_i	ΔL_H	$\Delta L_{H \pm i}$
1	0	-.036	-.036	+.036	+.062	+.098
1'	-.019	-.182	-.163	-.182	-.026	+.156
2	+.002	-.048	-.050	-.048	+.025	+.073
2'	+.005	-.075	-.080	-.075	+.062	+.137
3	+.014	-.005	-.019	-.005	+.138	+.143
3'	+.008	-.272	-.280	-.272	+.010	+.282
4	7.252	7.820	+.568	7.820	7.167	-.693
5	7.210	8.206	+.996	8.206	7.248	-.958
6	7.211	8.302	+1.091	8.302	7.339	-.963
7	7.205	8.075	+.870	8.075	7.165	-.910
8	3.739	3.735	-.004	3.735	3.719	-.016
9	7.120	7.378	+.158	7.378	7.028	-.350
10	7.129	7.375	+.246	7.375	6.996	-.379
11	+.135	+.114	-.021	+.114	+.134	+.020
11'	+.143	+.121	-.022	+.121	+.153	+.032
12	+.117	+.108	-.009	+.108	+.147	+.039
12'	+.140	+.127	-.013	+.127	+.150	+.023
13	+.117	+.116	-.001	+.116	+.119	+.003
13'	+.108	+.105	-.003	+.105	+.124	+.019
14	+.117	+.100	-.017	+.100	+.110	+.010
14'	+.114	+.098	-.016	+.098	+.112	+.014
15	+.107	+.106	-.001	+.106	+.131	+.025
15'	+.123	+.112	-.011	+.112	+.135	+.023
16	+.111	+.089	-.022	+.089	+.100	+.011
16'	+.099	+.082	-.017	+.082	+.106	+.024
17	+.112	+.111	-.001	+.111	+.114	+.003
17'	+.082	+.083	+.001	+.083	+.092	+.009
18	+.108	+.110	+.002	+.110	+.119	+.009
18'	+.086	+.087	+.001	+.087	+.091	+.004

Location of Points Measured







TOP VIEW (TERMINAL BOARDS)

ΔL_i = Distance from a "zero point" or between 2 opposite points before thermal exposure.

ΔL_H = Distance from "zero point" or between 2 opposite points after thermal exposure.

$\Delta L_{H \pm i}$ = Dimensional change caused by thermal exposure.

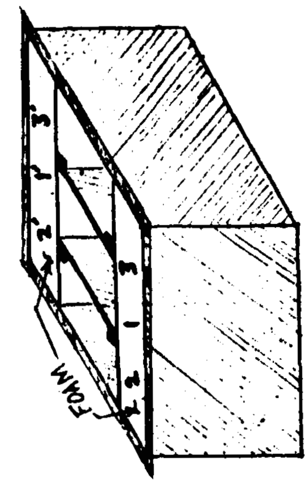
Manually Determined Dimensional Changes Distr. No. 1 - Phase IIIb "Timer", S/N 0000002 (PAGE 1 OF 2)	Table I Phase IIIb

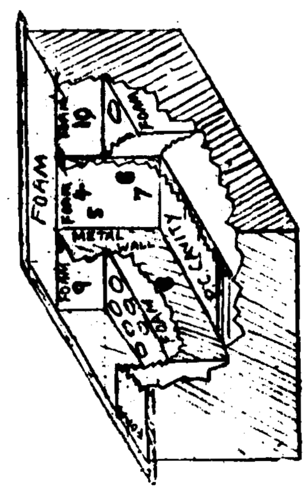
MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

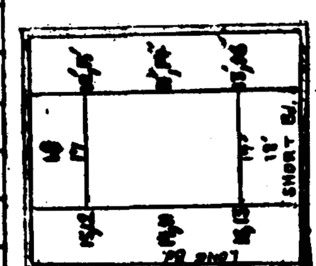
CYCLE: After Autoclave Cycle and After Oven Cycle

Points Measured	L_i (INCHES)	L_H (INCHES)	$L_H - L_i$ (INCHES)	L_i	L_H	$L_H - L_i$
1	0	+.062	+.062			
1'	-.019	-.026	-.007			
2	+.002	+.025	+.023			
2'	+.005	+.062	+.063			
3	+.014	+.138	+.124			
3'	+.008	+.010	+.002			
4	7.252	7.167	-.085			
5	7.210	7.248	+.038			
6	7.211	7.339	+.028			
7	7.205	7.165	-.042			
8	3.739	3.719	-.020			
9	7.120	7.028	+.092			
10	7.129	6.996	-.133			
11	+.135	+.134	-.001			
11'	+.143	+.153	+.010			
12	+.117	+.147	+.030			
12'	+.140	+.150	+.010			
13	+.117	+.119	+.002			
13'	+.108	+.124	+.016			
14	+.117	+.110	-.007			
14'	+.114	+.112	-.002			
15	+.107	+.131	+.024			
15'	+.123	+.135	+.012			
16	+.111	+.100	-.011			
16'	+.099	+.106	+.007			
17	+.112	+.114	±.002			
17'	+.082	+.092	.010			
18	+.108	+.119	+.011			
18'	+.086	+.091	+.005			

Location of Points Measured







TOP VIEW (TERMINAL BOARDS)

L_i = Distance from a "zero point" or between 2 opposite points before thermal exposure

L_H = Distance from "zero point" or between 2 opposite points after thermal exposure

$L_H - L_i$ = Dimensional change caused by thermal exposure

Manually Determined Dimensional Changes Distr. No. 1 Phase III b "Timer S/N0000002 (Page 2 of 2)	Tabel I Phase III

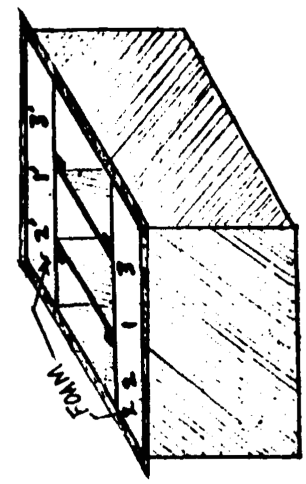
MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

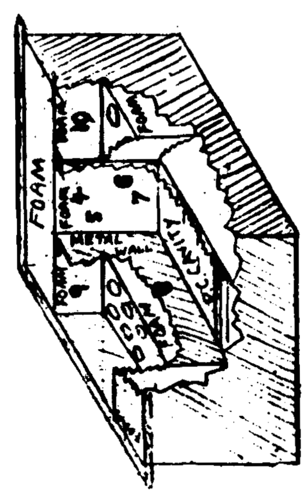
CYCLE: OVEN 160°F - 16 HR.

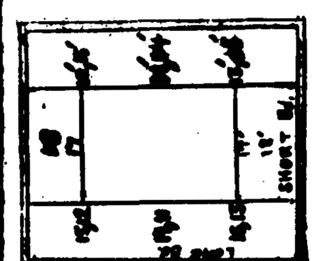
INCHES

Points Measured	ΔL_i	ΔL_H	ΔL_{H-i}	ΔL_i	ΔL_H	ΔL_{H-i}
1	+.042	+.185	+.143			
1'	+.051	+.196	+.145			
2	+.037	+.179	+.142			
2'	+.049	+.222	+.173			
3	+.044	+.188	+.144			
3'	+.047	+.159	+.112			
4	7.227	7.095	-.132			
5	7.227	7.131	-.096			
6	7.280	7.147	-.133			
7	7.256	7.153	-.103			
8	3.775	3.784	+.009			
9	6.967	6.800	-.167			
10	6.935	6.820	-.115			
11	+.109	+.122	+.013			
11'	+.092	+.102	+.010			
12	+.126	+.138	+.012			
12'	+.099	+.105	+.006			
13	+.113	+.143	+.030			
13'	+.099	+.118	+.019			
14	+.105	+.105	0			
14'	+.092	+.092	000			
15	+.108	+.111	+.003			
15'	+.103	+.107	+.004			
16	+.107	+.120	+.013			
16'	+.096	+.102	+.006			
17	+.085	+.086	+.001			
17'	+.087	+.086	-.001			
18	+.079	+.081	+.002			
18'	+.088	+.087	+.001			

Location of Points Measured







TOP VIEW (TERMINAL BOARDS)

ΔL_i = Distance from a "zero point" or between 2 opposite points before thermal exposure.

ΔL_H = Distance from "zero point" or between 2 opposite points after thermal exposure.

ΔL_{H-i} = Dimensional change caused by thermal exposure.

CON'T.

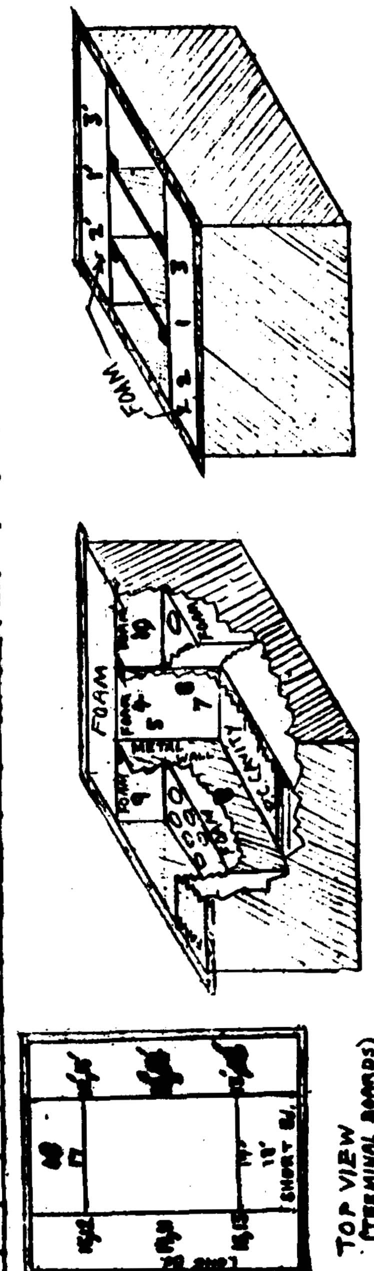
Manually Determined Dimensional Changes
Distr. No. 2 - Phase IIIb
"Thrust OK". S/N 0000018 (Page 1 of 3)

TABLE II
PHASE III a

MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

Points Measured	AUTOCLAVE 195°F-15PSI - 20HR. INCHES ΔL_I	ΔL_H	ΔL_{H-I}	OVEN 180°F - 24 HR. ΔL_I	ΔL_H	ΔL_{H-I}
1	+.185	+.257	+.072	+257	+.261	+.004
1'	+.196	+.261	+.065	+.261	+.267	+.006
2	+.179	+.193	+.014	+.193	+.205	+.012
2'	+.222	+269	+.047	+.269	+.276	+007
3	+.188	+.220	+.032	+.220	+.233	+.010
3'	+.159	+.195	+.036	+.195	+.199	+.004
4	7.095	7.066	-.029	7.066	7.039	-.027
5	7.131	7.086	-.045	7.086	7.050	-.036
6	7.147	7.061	-.086	7.061	7.031	-.030
7	7.153	7.018	-.135	7.018	6.991	-.027
8	3.784	2.756	-.028	3.756	3.757	+.001
9	6.800	6.795	-.005	6.795	6.790	-.005
10	6.820	6.782	-.038	6.782	6.760	-.022
11	+.122	+.125	+.003	+.125	.130	+.005
11'	+.102	+.103	+.001	+.103	+.108	+.005
12	+.138	+.142	+.004	+.142	+.143	+.001
12'	+.105	+.109	+.004	+.109	+.115	+.006
13	+.143	+.135	-.008	+.135	+.137	+.002
13'	+.118	+.117	-.001	+.117	+.120	+.003
14	+.105	+.114	+.009	+.114	+.116	+.002
14'	+.092	+.096	+.004	+.096	+.101	+.005
15	+.111	+.115	+.004	+.115	+.119	+.004
15'	+.107	+.112	+.005	+.112	+.117	+.005
16	+.120	+.115	-.005	+.115	+.119	+.004
16'	+.102	+.102	0	+.102	+.101	-.001
17	+.086	+.095	+.009	+.095	+.095	0
17'	+.086	+.086	0	+.086	+.086	0
18	+.081	+.094	+.013	+.094	+.095	+.001
18'	+.087	+.089	+.002	+.089	+.089	0

Location of Points Measured



ΔL_I = Distance from a "zero point" or between 2 opposite points before thermal exposure.

ΔL_H = Distance from "zero point" or between 2 opposite points after thermal exposure.

ΔL_{H-I} = Dimensional change caused by thermal exposure.

Manually Determined Dimensional Changes
Distr. No. 2 - Phase IIIb
"Thrust OK", S/N 0000018 (Page 2 of 2)

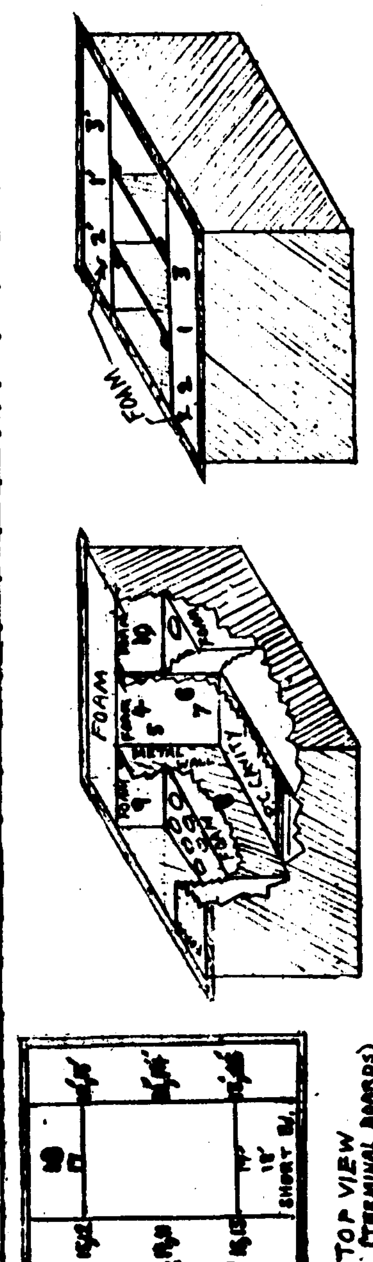
TABLE II
PHASE III

MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

CYCLE: After Autoclave and After Oven (180°) Cycle

Points Measured	INCHES L_i	L_H	L_{H-i}	L_i	L_H	L_{H-i}
1	+.185	+.261	+.077			
1'	+.196	+.267	+.071			
2	+.179	+.205	+.026			
2'	+.222	+.276	+.054			
3	+.188	+.233	+.045			
3'	+.159	+.199	+.040			
4	7.095	7.039	-.056			
5	7.131	7.050	-.081			
6	7.147	7.031	-.116			
7	7.153	6.991	-.162			
8	3.784	3.757	-.027			
9	6.800	6.790	-.010			
10	6.820	6.760	-.060			
11	+.122	+.130	+.008			
11'	+.102	+.108	+.006			
12	+.138	+.143	+.005			
12'	+.105	+.115	+.010			
13	+.143	+.137	-.006			
13'	+.118	+.120	+.002			
14	+.105	+.116	+.011			
14'	+.092	+.101	+.009			
15	+.111	+.119	+.008			
15'	+.107	+.117	+.010			
16	+.120	+.119	-.001			
16'	+.102	+.101	-.001			
17	+.086	+.095	+.009			
17'	+.086	+.086	0			
18	+.081	+.095	+.014			
18'	+.087	+.089	+.002			

Location of Points Measured



L_i = Distance from a "zero point" or between 2 opposite points before thermal exposure

L_H = Distance from "zero point" or between 2 opposite points after thermal exposure

L_{H-i} = Dimensional change caused by thermal exposure

Manually Determined Dimensional Changes
Distr. No. 2 - Phase IIIb
"Thrust OK", S/N 0000018 (Page 3 of 3)

TABLE XI
PHASE III-4

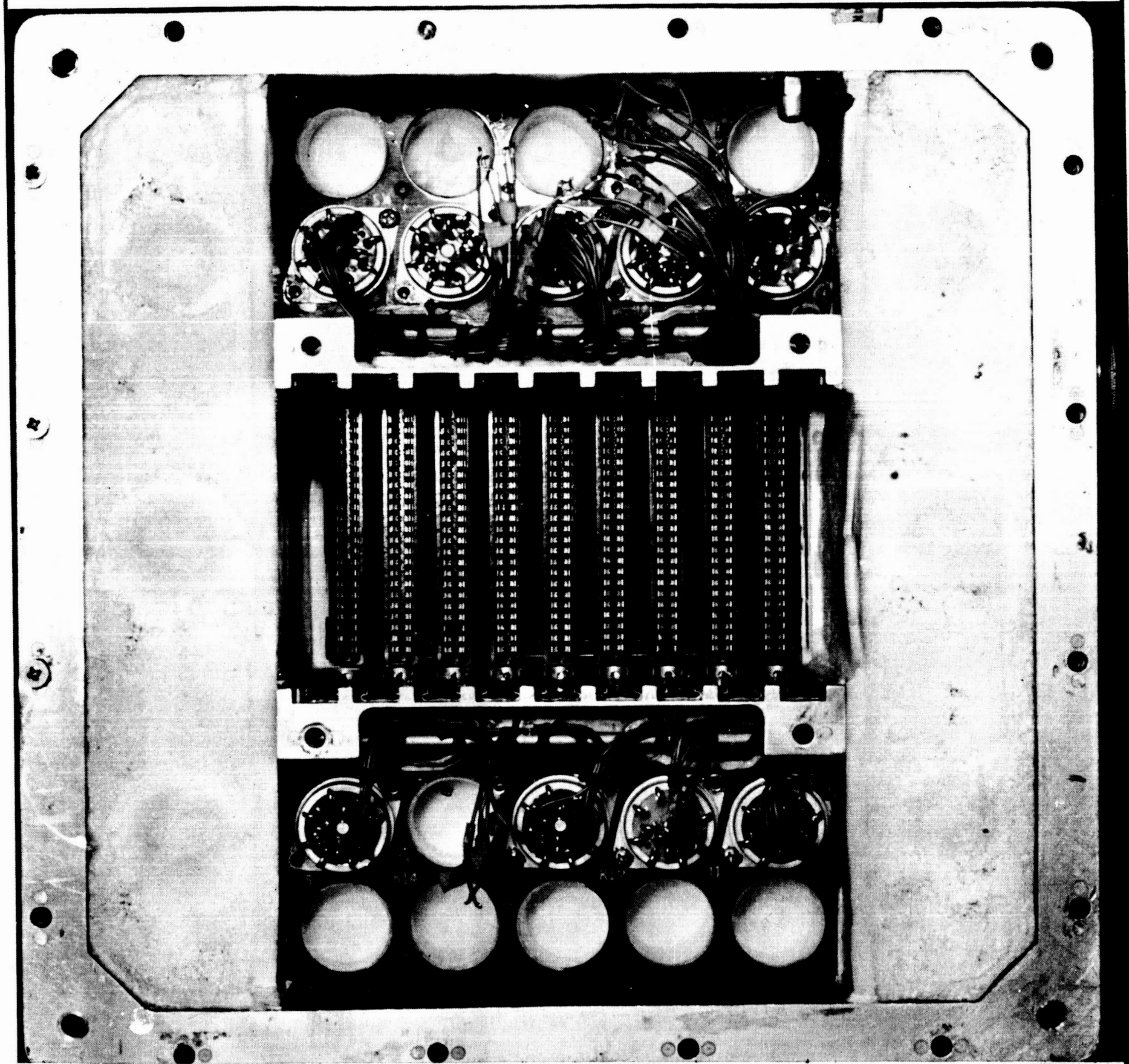


FIGURE 1a, PHASE IIIb

Distributor No. 1: Before Autoclave Cycle

Identity: "Timer", 60B62030-1, S/N 0000002, Mfg. 8/6/65

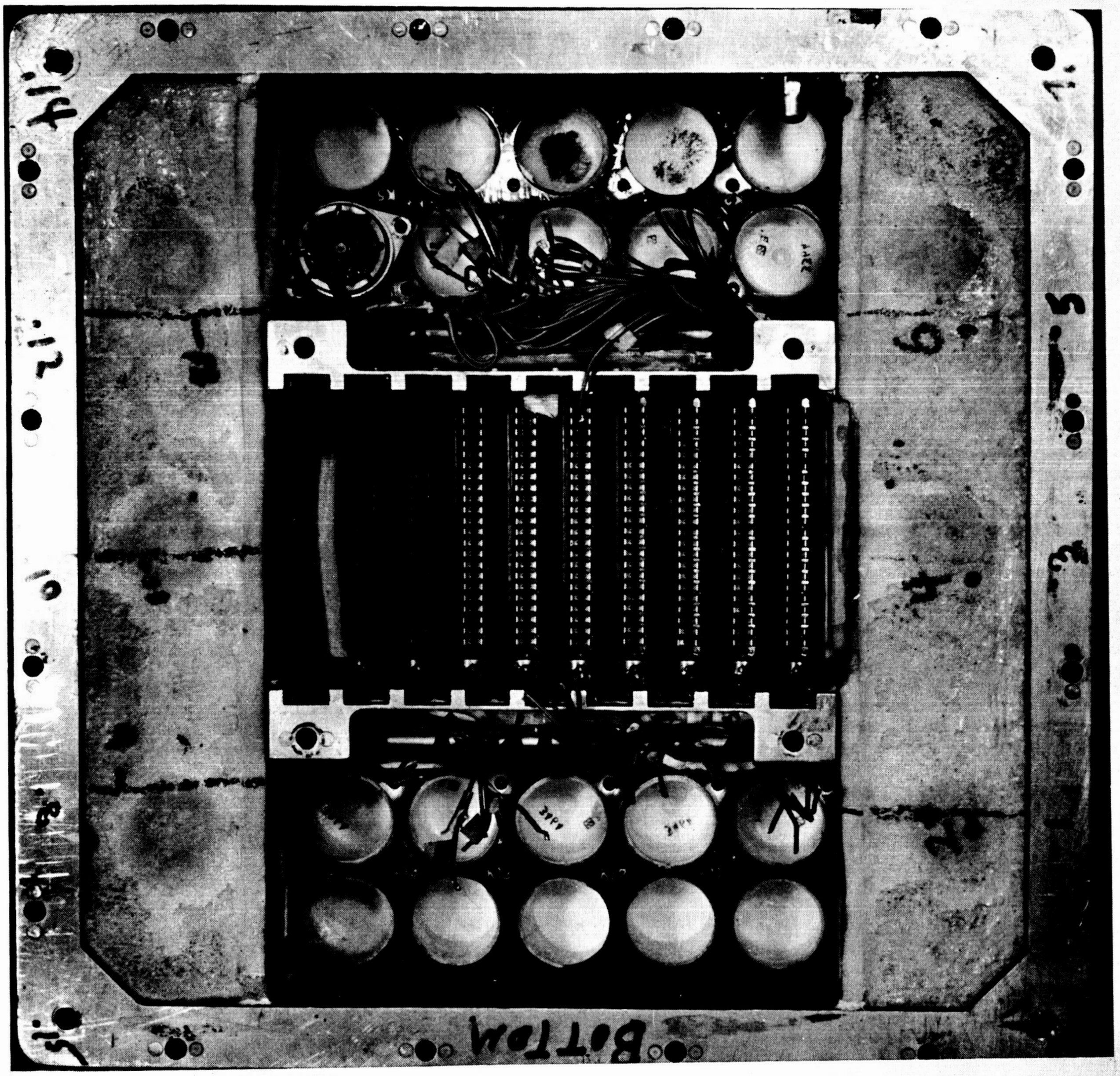


FIGURE 16, PHASE IIIb

Distributor No. 1: After Autoclave Cycle (170°F - 20 psig - 20 Hr.)

Identity: "Timer", 60B62030-1, S/N 0000002, Mfg. 8/5/65

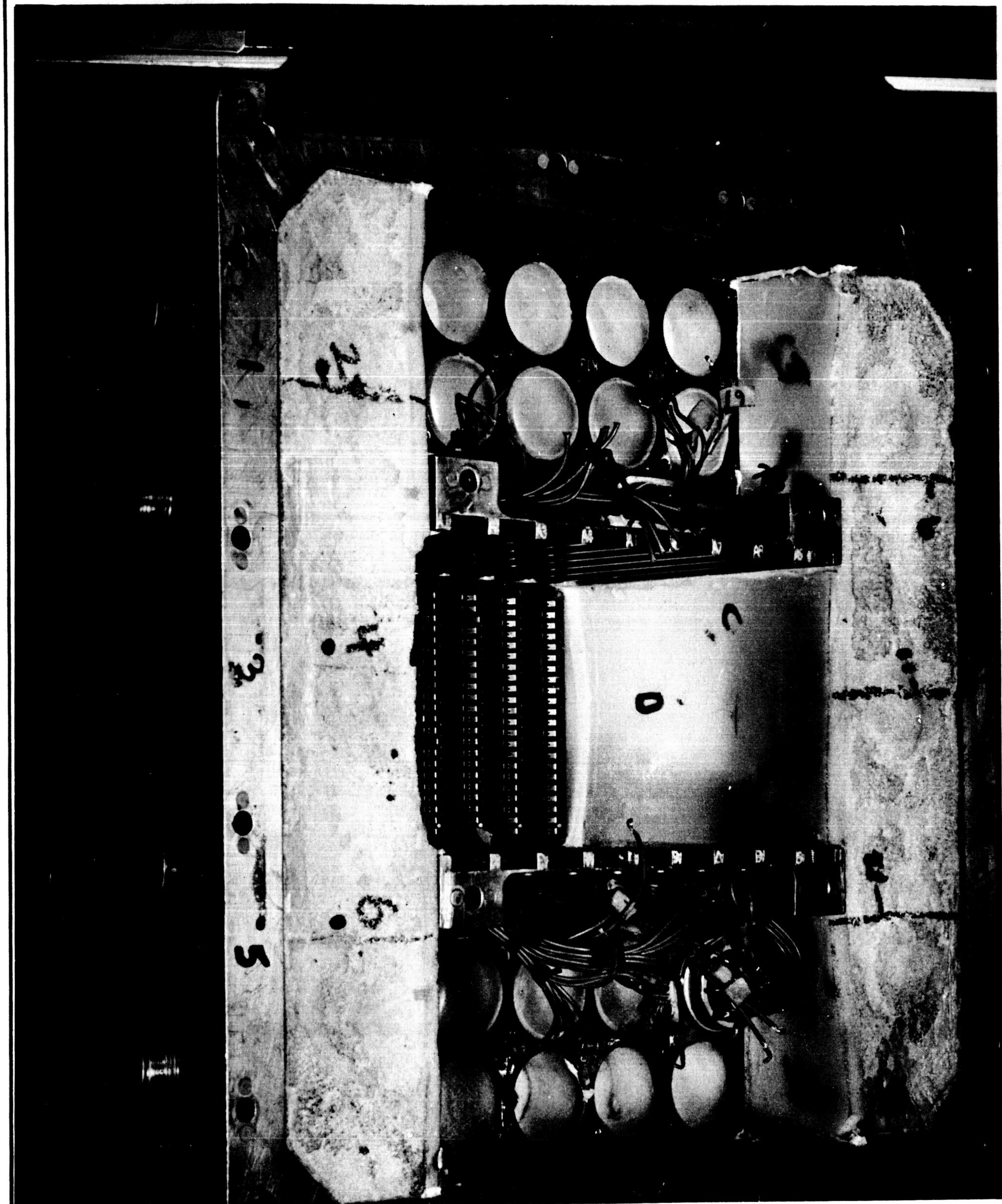


FIGURE 1c, PHASE IIIb

Distributor No. 1: After Autoclave Cycle (170°F - 20 psig - 20 Hr.)
Angle view to show depressed p.c. card cavity wall.
Identity: "Timer", 60B62030-1, S/N 0000002, Mfg. 8/5/65

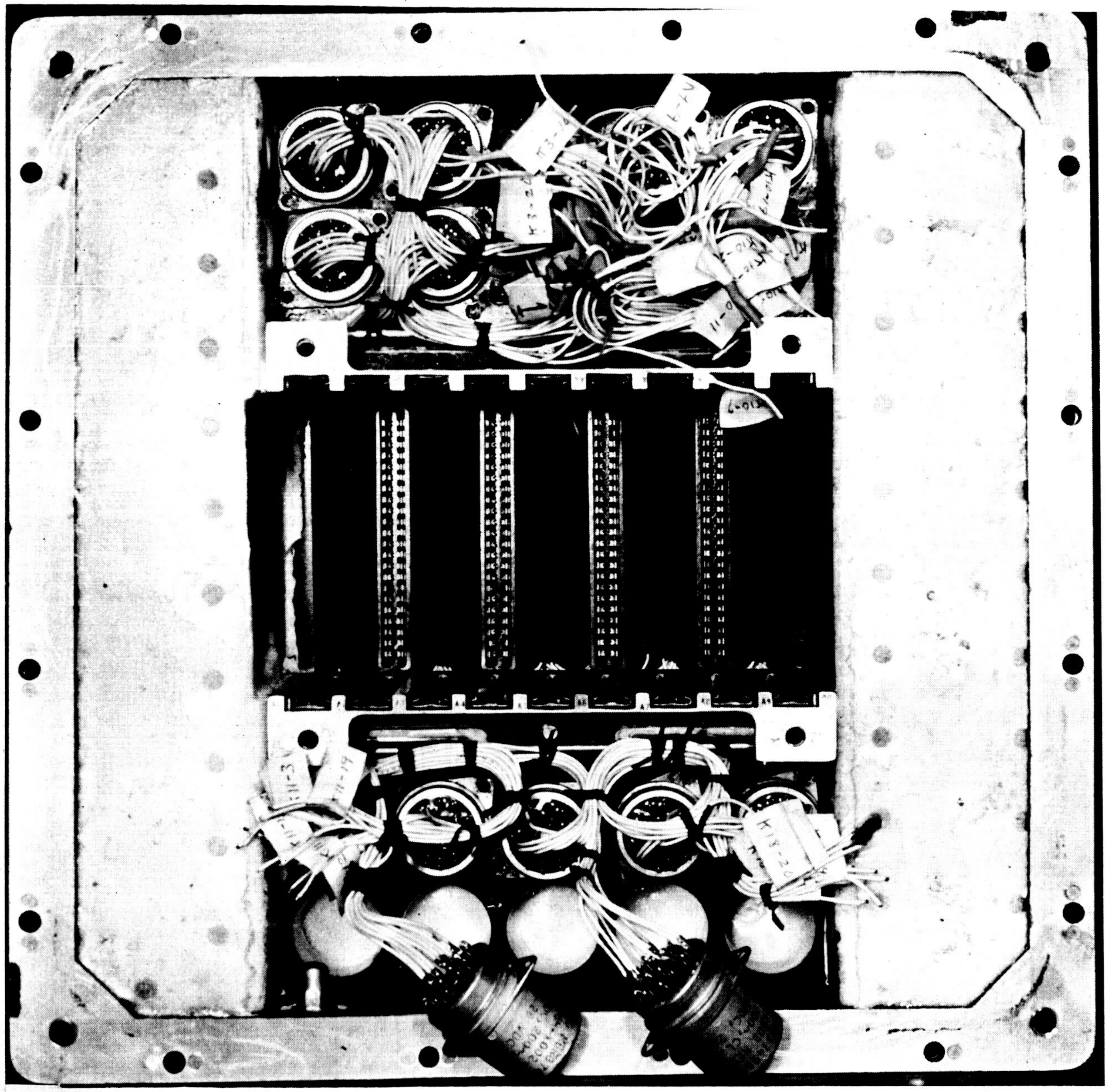


FIGURE 2, PHASE IIIb

Distributor No. 2: Before thermal Exposure

Identity: "Thrust OK", 60B62295-5A, S/N 00000018, Mfg. 7/1/66.

5.7 PHASE IIIc

5.7.1 Objective

To determine effects on post foam expansion when all hard outer foam surfaces are removed (i.e. Preformed dams and skin from horizontal (bottom) surface).

5.7.2 Identity of Distributor Tested

"Propulsion Distributor", 60B62029-7A, S/N 0000013, Mfg. 6/28/66.

History: Previously subjected to BRT but not exposed to elevated temperatures that effected foam expansion. Figure 1 shows this distributor after trimming but before oven exposure.

5.7.3 Test Procedure

5.7.3.1 Specimen Preparation

The preformed dam was removed from the ends of p.c. card cavity and relay cavity areas. (The thickness of the dam was approximately .3"). The horizontal (bottom) surface was cut out to a nominal depth of 1/10".

(Note: To remove the dams it was necessary to cut through the dam along the adjoining metal wall of the p.c. card cavity. While doing this, a wire, which was lying against the back side of the dam was cut. These wires can be seen in Figure 1.)

5.7.3.2 Test Conditions and Determinations

The distributor was reassembled and subjected to a 180°F oven cycle for 16 hours. The effects on continuity were determined with a Bendix Analyzer. Dimensional changes were determined, manually, as in Phase IIa.

5.7.4 Test Results

5.7.4.1 Presentation of Results

Table I shows the dimensional changes that took place during the oven cycle. Figure 1 shows the distributor after trimming and before heating. No after heating pictures were taken.

5.7.4.2 Effects on Electrical Continuity

No open circuits resulted from the foam expansion as indicated by testing with a Bendix Analyzer before and after heating.

5.7.4.3 Effects on Dimensions (Table I)

The foam expanded vertically against the bottom cover. Lateral expansion decreased the distance between opposite foam walls of the cavities from .2" to .3". This lateral expansion would probably have been greater if the foam had not had room to expand vertically. Even with this degree of expansion the foam did not touch p.c. cards - inserted afterwards.

The maximum expansion on the terminal board side was only .07". This is comparable to results obtained in other test phases.

5.7.5 Conclusions

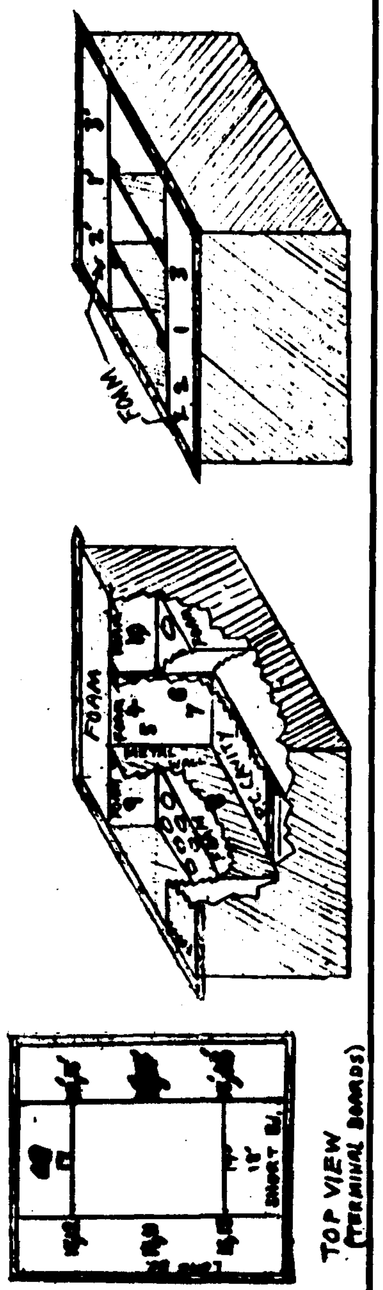
Removal of the outer surfaces of the foam masses will not prevent the foam from expanding. However the results indicated that proper trimming of the surfaces will minimize the degree of lateral expansion against the p.c. cards and Union Switch Relays; also trimming will reduce the degree of deflection of the terminal boards.

MANUALLY DETERMINED DIMENSIONS BEFORE & AFTER THERMAL CYCLE

CYCLE: OVEN 180°F - 16 HR.

Points Measured	L_i	INCHES L_H	$L_H - L_i$	L_i	L_H	$L_H - L_i$
1	-.067	+.002	+.069			
1'	-.100	-.005	+.095			
2	-.037	0	+.037			
2'	-.089	-.007	+.082			
3	-.072	+.005	+.077			
3'	-.048	0	+.048			
4	7.584	7.312	-.272			
5	7.534	7.330	-.204			
6	7.535	7.240	-.295			
7	7.527	7.255	-.270			
8	3.763	3.765	+.002			
9	7.640	7.345	-.295			
10	7.522	7.212	-.310			
11	+.084	+.110	+.026			
11'	+.085	+.108	+.023			
12	+.075	+.089	+.014			
12'	+.083	+.104	+.021			
13	+.098	+.122	+.024			
13'	+.087	+.114	+.027			
14	+.090	+.104	+.014			
14'	+.087	+.094	+.007			
15	+.079	+.093	+.014			
15'	+.081	+.099	+.018			
16	+.100	+.116	+.016			
16'	+.087	+.098	+.011			
17	+.074	+.085	+.011			
17'	+.080	+.099	+.019			
18	+.070	+.092	+.072			
18'	+.088	+.091	+.003			

Location of Points Measured



L_i = Distance from a "zero point" or between 2 opposite points before thermal exposure

L_H = Distance from "zero point" or between 2 opposite points after thermal exposure

$L_H - L_i$ = Dimensional change caused by thermal exposure

Manually Determined Dimensiona Changes "Propulsion Distr.", S/N 0000013

TABLE I

PHASE III

111

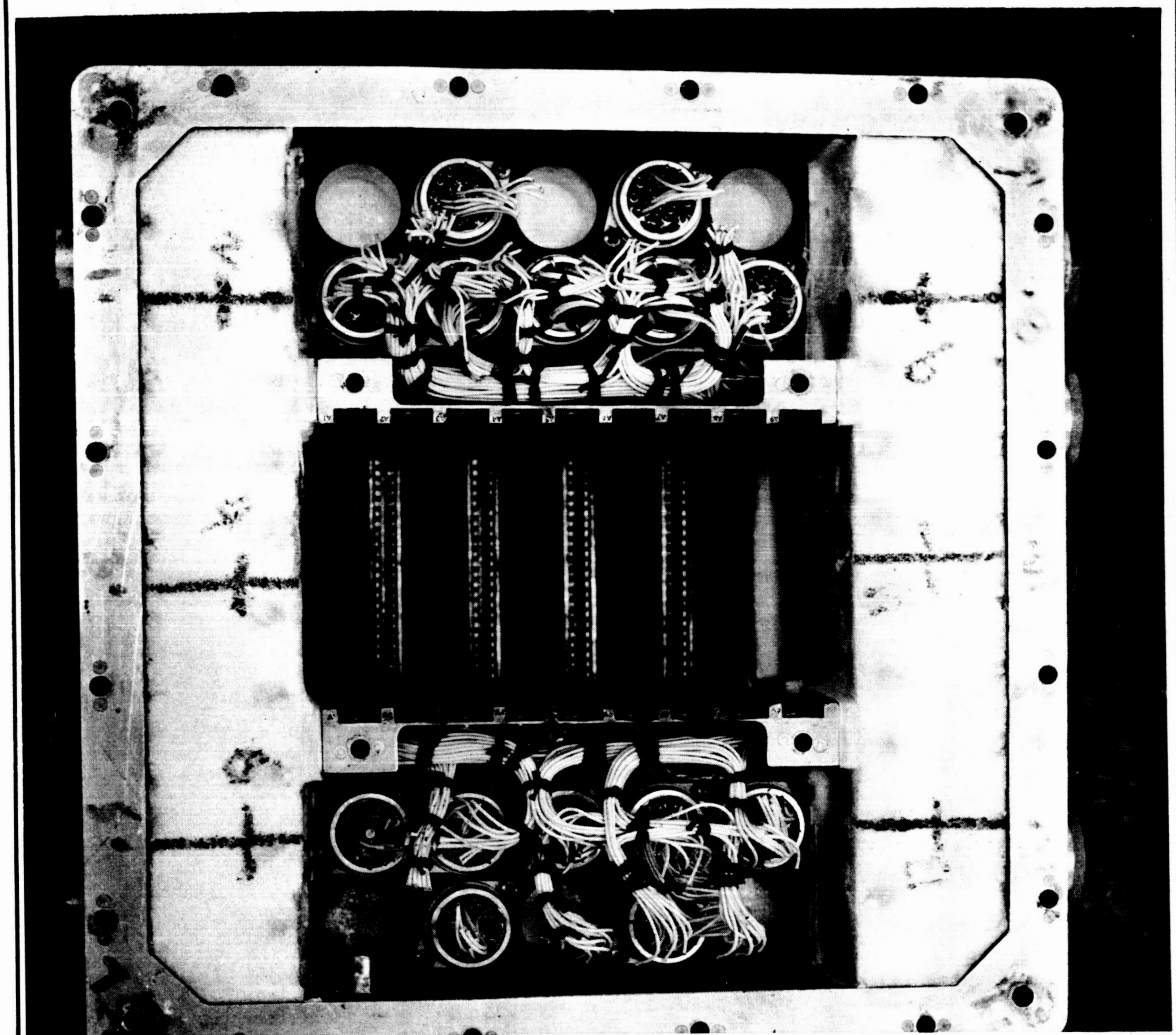


FIGURE 1, PHASE IIIc

After trimming; Before Oven Cycle

Identity: "Propulsion Distributor", 60B62029-7A, S/N 0000013, Mfg. 6/28/66